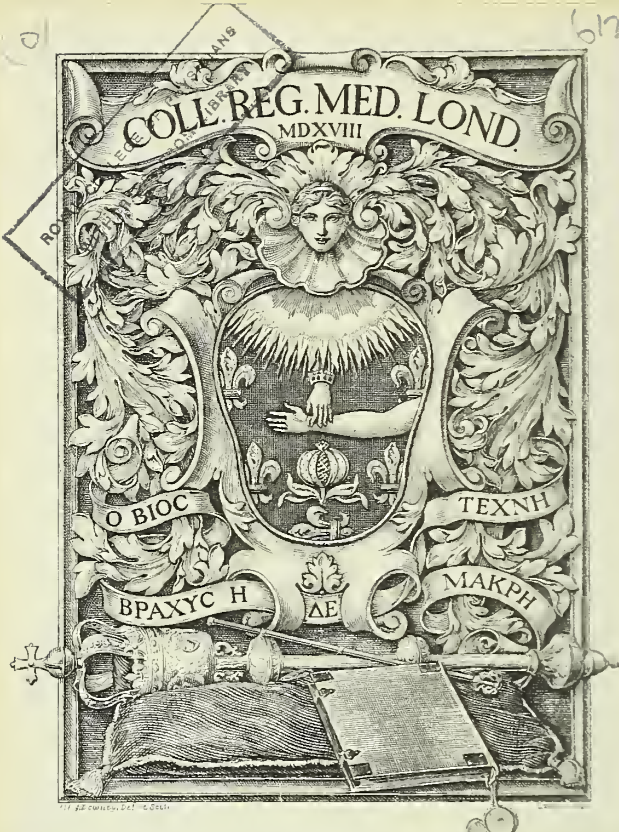
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A

TREATISE

OF THE

Animal Oeconomy.

BY

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PREFACE.

IN *the following Treatiſe I have avoided* Hypotheſes, *and explained the* Laws *which obtain in Human Bodies by Reaſon and Experiments.* Hypotheſes, *of whatever Nature, are not to be admitted in Philoſophy. Now whatever is not deduced from the* Phænomena, *is to be called an* Hypotheſis.

Harvey *from Experiments and Obſervations traced out the Circular Motion of the Blood. After him* Lower *made ſome farther Diſcoveries concerning that Motion, and the Cauſes by which it may be diſturbed. After theſe great Men, the Knowledge of the* Animal Oeconomy *received no very conſiderable Improvement, till Sir* Iſaac Newton *diſcovered the Cauſes of* Muſcular Motion, *and* Secretion; *and likewiſe furniſhed Materials for explaining* Digeſtion, Nutrition, *and* Reſpiration. *To Him I am chiefly indebted for what I have delivered on thoſe Heads.*

A

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Animal Oeconomy.

IN this Treatiſe I ſhall give an Account of the principal Parts of the *Animal Oeconomy*; which I ſhall explain, not by Hypotheſes, but by Reaſon and Experiments. The Parts I ſhall treat of, are *Muſcular Motion, the Motion of the Blood, Reſpiration, Digeſtion and Nutrition,* *Secretion, and the Discharges of Human Bodies.*

In order to explain *the Motion of the Blood*, I shall premise an Account of *the Motion of Fluids thro' Cylindrical Pipes,* and prove the Properties of that Motion by Experiments.

SECTION I.

Of the Motion of Fluids through Cylindrical Pipes.

Proposition I.

IF a Fluid *be moved through a Cylindrical Pipe made of a given Sort of Matter, by a* Force *acting constantly and uniformly during the whole* Time *of the Motion; its Velocity, setting aside the Resistance of the Air, will be in a Ratio compounded of the subduplicate Ratio of the moving* Force *directly, and the subduplicate Ratios of* *of the Diameter and Length of the Pipe taken together inversly. If* F *denote the moving* Force, D *and* L *the Diameter and Length of the Pipe; I say, that* V *will be proportional to* $\sqrt{\frac{F}{DL}}$.

For the whole Motion of the Fluid flowing thro' the Pipe will, like all other Motions, be measured by the Quantity of Matter moved and its Velocity taken together. But the Quantity of Matter moved is in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith the Fluid flows through the Pipe, and of the Time of the Motion. For the Quantity of Matter or Weight of Fluid contained in the Pipe is opposed to the moving Force during the whole Time of its Action, and must be moved by it for every indefinitely ſhort Cylinder of Fluid diſcharged by the Pipe; that is, as often as there are phyſical Points in the Length of another Cylindrical Pipe of an equal Diameter with that thro' which the Fluid flows, and of ſuch a Length as that it can juſt contain the Quantity of Fluid diſcharged in the Time of the Motion; which Length being as the Velocity of the Fluid flowing through the Pipe and the Time of the Motion taken together; the Quantity of Matter moved will be in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith it flows thro' the Pipe, and of the Time of the Motion. And the whole Motion, which is as the Quantity of Matter moved and its Velocity taken together, will be in a Ratio compounded of the ſimple Ratios of the Quanti-

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ty of Matter or Weight of Fluid contained in the Pipe, and of the Time of the Motion; and of the duplicate Ratio of the Velocity: Therefore, putting T for the Time of the Motion, the whole Motion will be as QTV^2.

Setting aside the Resistance of the Air, this Motion would be proportional to the moving Force and Time of its acting taken together; that is QTV^2 would be proportional to FT, if the internal Surface of the Pipe by Friction, or Attraction, or both did not act continually upon the Fluid moving through it, and cause a Change in its Motion proportional to the Efficacy wherewith it acts; which Efficacy in a Pipe made of a given Sort of Matter is measured by the Ratio of the internal Surface of the Pipe to the Quantity of Fluid contained in it; that is, by DL applied to Q.

And

And by Consequence $\frac{QTV^2DL}{Q}$ will be proportional to FT, and therefore V will be proportional to $\sqrt{\frac{F}{DL}}$.

Cor. 1. If the moving Force and Diameter of the Pipe be both given; the Velocity, setting aside the Resistance of the Air, will be in the inverse subduplicate Ratio of the Length of the Pipe. If F and D be given; V will be as $\frac{1}{\sqrt{L}}$.

Cor. 2. If the moving Force be as the Quantity of Fluid contained in the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe and Density of the Fluid taken together. Putting $\triangle$ for the Density of the Fluid, if F be as $D^2L\triangle$; then V will be as $\sqrt{D\triangle}$.

Cor.

Cor. 3. If the moving Force be as the Quantity of Fluid contained in the Pipe, and the Denſity of the Fluid be given; the Velocity, ſetting aſide the Reſiſtance of the Air, will be in the ſubduplicate Ratio of the Diameter of the Pipe. If F be as $D^2L\triangle$, and $\triangle$ be given; then V will be as $\surd D$.

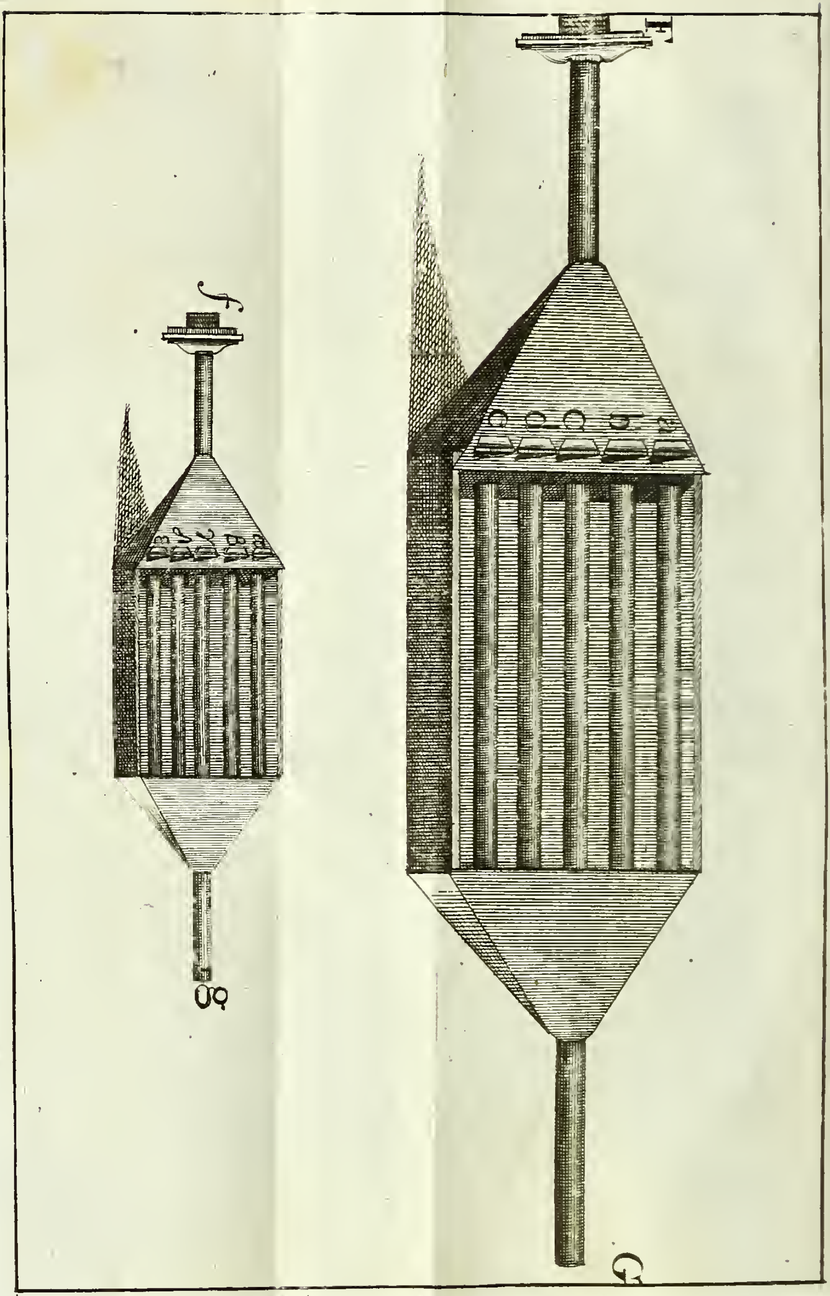
Cor. 4. If the moving Force be proportional to the Square of the Diameter of the Pipe, and the Length of the Pipe be given; the Velocity, ſetting aſide the Reſiſtance of the Air, will be in the ſubduplicate Ratio of the Diameter of the Pipe. If F be as D^2, and L be given; then V will be as $\surd D$.

Cor. 5. If the moving Force be as the Square of the Diameter of the Pipe; the Velocity, ſetting aſide the Reſiſtance of the Air, will be be in a Ratio compounded of the ſubduplicate Ratio of the Diameter of the Pipe directly, and the ſubduplicate Ratio of its Length inverſly. If F be as D^2; then will V be as $\sqrt{\frac{D}{L}}$.

Cor. 6. If the moving Force be as the Capacity of the Pipe, if the Diameter of the Pipe be in the ſubduplicate Ratio of its Length; the Velocity, ſetting aſide the Reſiſtance of the Air, will be in the ſubquadruplicate Ratio of the Length of the Pipe. If F be as D^2L, and D be as $\sqrt{L}$; then will V be as $L^{\frac{1}{4}}$.

Cor. 7. The moving Force, ſetting aſide the Reſiſtance of the Air, will be in a Ratio compounded of the duplicate Ratio of the Velocity, and of the ſimple Ratios of the Diameter and Length of the Pipe. F will be as V^2DL.

Proof



Proof by Experiments.

TO prove the Truth of this Propoſition by Experiments, I procured ſeveral Cylindrical Pipes of Braſs of different Diameters and Lengths, each of which Pipes had one End fitted to ſcrew into the Side of a Veſſel filled with Water at three different Diſtances from its Top, namely at the Diſtances of one Foot, two Feet, and four Feet. The Veſſel made for theſe Experiments was a ſquare Wooden Veſſel ſomething above four Feet in Depth, and nine Inches of a *London* Foot in its internal Length and Breadth.

Before I give an Account of the Experiments, it will be neceſſary to ſhew how to meaſure the moving Forces and Velocities of Water flowing thro' Cylindrical Pipes ſcrewed into the Side of a Veſſel filled with Water.

To meaſure the moving Force of Water flowing through a Cylindrical Pipe ſcrew'd into the Side of a Veſſel filled with Water, we muſt know the Area of the Top of the Water in the Veſſel, the Area of the Orifice of the Pipe, the perpendicular Diſtance of the Place of the Pipe's Inſertion into the Side of the Veſſel from the Top of the Water, and the Situation of the Pipe with reſpect to the Horizon.

Let the Area of the Top or upper Surface of the Water in the Veſſel be called A, the Area of a Hole made in the Bottom or Side of the Veſſel be called a, and the perpendicular Diſtance of the Place of Inſertion of the Pipe from the Top of the Water be called H; and then, by *prop.* 36. *lib.* 2. *Princip. Newton.*, the Velocity of the Water flowing out of of the Hole, ſetting aſide the Reſiſtance of the Air, will be equal to the Velocity which a heavy Body would acquire in falling perpendicularly and without Reſiſtance thro' the Space $\frac{A^2 H}{A^2 - a^2}$. And, by the ſecond *Corollary* of the ſame *Propoſition*, the Force generating the whole Motion of the effluent Water will be equal to the Weight of a Cylinder of Water whoſe Baſe is $\frac{12}{17}$ parts of the Area of the Hole or a, and whoſe Height is $\frac{2 A^2 H}{A^2 - a^2}$. If the Area of the Hole be exceedingly ſmall when compared with the Area of the upper Surface of the Water; that is, if a be exceeding ſmall when compared with A; the Height $\frac{2 A^2 H}{A^2 - a^2}$ will be very nearly equal to 2H; and by Conſequence the Force generating the whole Motion of the effluent Water will be very nearly equal to the Weight of a Cylinder of Water whose Base is $\frac{12}{17}$ a, and whose Height is 2H; that is very nearly equal to the Weight of the Cylinder $\frac{24}{17}$ a H: But the Weight of this Cylinder is proportional to the Weight of the Cylinder a H, because $\frac{24}{17}$ is an invariable Quantity: And therefore when the Area of the Hole is extremely small in comparison of the Area of the Top of the Water, the Force generating the whole Motion of the effluent Water will be very nearly proportional to the Weight of the Cylinder a H.

The Force generating the Motion of Water flowing thro' a Cylindrical Pipe screw'd into the Side of a Vessel fill'd with Water, and laid parallel to the Horizon, is something greater than the Force generating the Motion of Water flowing through a Hole of a Diameter equal to that of the Pipe, and which

is

is placed at an equal Diſtance from the Top of the Water; as will appear by conſidering the Nature of theſe two Motions.

In obſerving the Motion of Water flowing through a Hole made in the Side of a Veſſel, we may perceive the Vein not to fill the Hole. Sir *Iſaac Newton*, in determining this Motion from Experiments, found the Vein, after it had paſſed out of the Hole, to grow ſmaller and ſmaller, till it came to a Diſtance very nearly equal to the Diameter of the Hole; at which place he meaſured the Diameter of the Vein, and found it to be to the Diameter of the Hole, as 21 to 25. The Area of a tranſverſe Section of the Vein at that Diſtance from the Hole, is to the Area of the Hole; as the Square of the Diameter of the Vein, to the Square of the Diameter of the Hole; that is, as 12 is to 17 nearly. This

Con-

Contraction of the Vein ariſes from the Nature of the Motion of the Water down the Veſſel: For the Water falls down from the Top of the Veſſel to the Hole not perpendicularly but obliquely, its Parts moving laterally as well as downwards. By this oblique Motion it is, that the Column of the deſcending Water grows narrower perpetually from the Top of the Water to the Hole, and to a ſmall Diſtance beyond it; and that the Vein does not fill the Hole, but falls within it, leaving a little empty Space all round. On account of this Contraction of the Vein leſs Water flows out, and by Conſequence leſs Motion is generated in a given Time, than would be produced, if the Diameter of the Vein at the Hole was exactly equal to the Diameter of the Hole. And as leſs Motion is generated, ſo the moving Force is likewiſe leſs; being only

only equal to the Weight of a Cylinder of Water whoſe Magnitude is $\frac{24}{17}$aH, when the Hole is extremely ſmall in compariſon of the upper Surface of the Water; whereas it would be equal to the Weight of a Cylinder of Water whoſe Magnitude is 2aH, if the Vein filled the Hole and had no Contraction beyond it. And therefore the moving Force is leſs than it would be if the Vein filled the Hole and had no Contraction beyond it, in the Proportion of 12 to 17.

If inſtead of flowing through the Hole into the open Air, the Water flows through the Hole into a Cylindrical Pipe and through that into the Air, and if the Diameter of the Hole be equal to that of the Pipe; the Force generating the Motion of the Water flowing through the Pipe will be different from the

Force

Force generating the Motion of the Water flowing through the Hole.

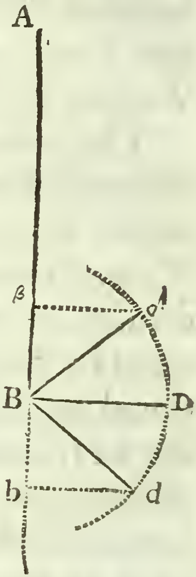
Firſt, let us ſuppoſe the Pipe to lie parallel to the Horizon; and then the Force generating the Motion of the Water flowing through it will be greater than the Force generating the Motion of the Water flowing through the Hole. For the Weight of Water in the Pipe, and the Reſiſtance ariſing from the internal Surface of the Pipe, do both of them, by acting in a kind of Oppoſition to the Weight of the deſcending Cataract in the Veſſel, retard the Motion of the Cataract, and hinder it from flowing ſo faſt into the Pipe, as it does through the Hole into the open Air. And by this Oppoſition they make the Baſe of the Cataract at its Entrance into the Pipe to ſpread and grow broader, and by Conſequence encreaſe the moving Force, and make

make it greater than the Force generating the Motion of the Water flowing through the Hole. Hence it is evident, that the moving Force will encreaſe, either on encreaſing the Length of the Pipe or leſſening its Diameter; and will be greateſt, when the Pipe is infinitely long or infinitely narrow: In which Caſes the Baſe of the Cataract at its Entrance into the Pipe will exactly fill it, and the moving Force will be equal to the Weight of the Cylinder of Water 2 a H; and by Conſequence will be greater than the Force generating the Motion of the Water flowing through the Hole, in the Proportion of 12 to 17, and the Motion generated in the Water flowing thro' the Pipe will be greater than the Motion generated in the Water flowing thro' the Hole; and the Difference of theſe two Motions will be greater when the Pipe is long or narrow, than when it is ſhort or wide. And therefore, if we ſuppoſe the Forces generating the Motions of Water flowing through Cylindrical Pipes laid parallel to the Horizon, to be equal to the Forces generating the Motions of Water flowing through Holes of equal Diameters, and placed at equal perpendicular Diſtances from the upper Surface of the Water in the Veſſel, on which Suppoſition the Force generating the Motion of Water flowing through a Pipe will be proportional to the Weight of a Cylinder of Water whoſe Magnitude is aH, the Motion of the Water flowing thro' a longer or a narrower Pipe, when compared with the Motion of the Water flowing thro' a ſhorter or a wider Pipe, will be found by Experiments to be ſomething greater than it ought to be on this Suppoſition of the moving Force.

But

But the Difference will be but ſmall in Pipes of ſmall Lengths and Diameters, and therefore in the following Experiments, when a Pipe lies horizontally, I ſhall ſuppoſe the moving Force to be proportional to the Weight of the Cylinder aH.

The moving Force will become different when the Pipe is inclined to the Horizon. The Weight of Water in the Pipe, as far as it encreaſes or leſſens the Motion generated by the Force which is proportional to the Weight of the Cylinder aH, muſt be added to or ſubducted from that Weight; and the Sum or Difference will be proportional to the Force generating the Motion of the Water flowing thro' the Pipe in that inclined Poſition. The part of the Weight of the Water in the Pipe which is to be added to or ſubducted from the Weight of the Cylinder aH may be thus determined. Let BD be a Cylindrical Pipe, lying parallel to the Horizon, with its End B inserted into the Side of the Vessel at the perpendicular Distance of BA from the Top of the Water; the Force generating the Motion of the Water flowing thro' this Pipe, is proportional to the Weight of the Cylinder a×AB, because in this Case H is equal to AB. Let the Pipe be turned from its horizontal Position, either



downwards into the Position Bd, or upwards into the Position Bδ; and then the moving Force will be changed, and be proportional to the Weight of the Cylinder a×Ab in the first Case, and to the Weight of the Cylinder a×Aβ in the second. For

the

the Weight of the Water in the Pipe Bd encreaſeth the Motion of the Water flowing through it, and the part of this Weight which is wholly ſpent in encreaſing the Motion, is, from the Laws of Motion of Bodies down inclined Planes, the $\frac{Bb}{Bd}$ part of the Weight of Water contained in the Pipe, or of the Cylinder $a \times Bd$; and therefore is equal to the Weight of the Cylinder $a \times Bb$. This Weight added to the Weight of the Cylinder $a \times AB$ gives the Weight of the Cylinder $a \times Ab$, which Weight is the Force generating the Motion of the Water flowing thro' the Pipe Bd. The Weight of Water in the Pipe $B\delta$ leſſens the Motion of the Water flowing thro' it, and the part of the Weight which is wholly ſpent in leſſening the Motion, is the Weight of the Cylinder $a \times B\beta$. This Weight ſubducted from the

the Weight of the Cylinder a×AB, leaves the Weight of the Cylinder a × A β, which Weight is the Force generating the Motion of the Water flowing through the Pipe Bδ.

If B be made the Center of a Circle, and Bd or B δ the Radius, Bb will be the right Sine of B d b the Angle of Depreſſion of the Pipe below the Plane of the Horizon, and Bβ will be the right Sine of B δ β the Angle of its Elevation above it. And by Conſequence, when the Pipe is depreſſed below the Horizon; the moving Force will be proportional to the Weight of a Cylinder of Water, of a Baſe equal to the Orifice of the Pipe, and of a Height equal to the Sum of the perpendicular Height of the Water in the Veſſel above the Place where the Pipe is inſerted and the right Sine of the Angle of Depreſſion of the Pipe below the Plane of the Horizon: And when the Pipe

is

is elevated above the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whoſe Baſe is equal to the Orifice of the Pipe, and whoſe Height is equal to the Difference of the perpendicular Height of the Water in the Veſſel above the Place of Inſertion and the right Sine of the Angle of Elevation of the Pipe above the Plane of the Horizon. If S denote the right Sine of the Angle in which the Pipe is depreſſed below or elevated above the Plane of the Horizon, the moving Force will be proportional to the Weight of the Cylinder $a \times \overline{H+S}$ when the Pipe is depreſſed below the Horizon, and proportional to the Weight of the Cylinder $a \times \overline{H-S}$ when it is elevated above it; and comprehending both Caſes in one Expreſſion, the moving Force will be as $a \times \overline{H \pm S}$, or as $D^2 \times \overline{H \pm S}$, very nearly.

To meaſure the Velocity of Water flowing through a Cylindrical Pipe ſcrew'd into the Side of a Veſſel filled with Water. V by this *Propoſition* is as $\sqrt{\frac{F}{DL}}$; or as $\sqrt{\frac{D^2 \times \overline{H \pm S}}{DL}}$, or as $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$.

And therefore $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ will be one Meaſure of the Velocity. Another Meaſure of it may be had from Experiments. For the Velocity of Water flowing through a Cylindrical Pipe, lying either parallel or inclined to the Horizon, is proportional to the Quantity of Water diſcharged in a given Time apply'd to the Orifice of the ſtipe. For the Quantity diſcharged in a given Time apply'd to the Orifice of the Pipe, will give the Length of a Cylindrical Pipe which can juſt contain that Quantity; which Length

is

is the Space that would be defcribed in the Time of the Motion by an uniform Velocity, equal to the Velocity wherewith the Fluid flows through the Pipe when the moving Force acts conftantly and uniformly, as it will do if the Veffel be kept conftantly full by pouring in Water very gently at the Top as faft as it runs out of the Pipe. But the Velocities of all uniform Motions are as the Spaces defcribed in a given Time; and by Confequence, the uniform Velocity wherewith the Length of the faid Cylinder would be defcribed in the given Time of the Motion, will be proportional to that Length; and therefore proportional to the Quantity of Fluid difcharged apply'd to the Orifice of the Pipe. Let M denote the Quantity of Water difcharged in the given Time of the Motion; and then the Velocity V will be proportional to, and consequently measured by $\frac{M}{a}$; or $\frac{M}{D^2}$, because Circles are to one another as the Squares of their Diameters.

If the Velocity be rightly measured by this *Proposition*; then $\sqrt{\frac{D \times H \pm S}{L}}$ must be proportional to $\frac{M}{D^2}$ very nearly, as it will appear to be by the following Experiments, setting aside the Resistance of the Air.

Tho' in this *Proposition* I have set aside the Resistance given by the Air to this Motion, yet it will be necessary to consider it, in order rightly to understand the Disturbances in the Motion caused by it. Water in flowing out of a Pipe into the open Air communicates a Motion to the Air, and loses so much of its own Motion as it communicates. Now if we suppose the Motion

tion communicated to be proportional to the Square of the Diameter of the Vein of the effluent Water and the Square of its Velocity, taken together; then the Motion communicated to the Air, with reſpect to the Motion which in the ſame time would be generated in the Water if the Air gave no Reſiſtance, will be reciprocally as the Length of the Pipe. And by Conſequence, in Pipes of the ſame Length, the Motions communicated to the Air, will on this Suppoſition be proportional to the Motions of the Water which would be generated if there was no Air, but the Water flow'd out of the Pipes into an empty Space perfectly void of all Matter. And therefore the Reſiſtance of the Air will cauſe no Diſturbance in the Proportions of the Motions of the Water flowing through ſuch Pipes. This Suppoſition, that the Veins of the effluent Water are reſiſted by the Air in Proportion to the Squares of their Diameters and the Squares of their Velocities taken together, will not appear unreaſonable, when we conſider that ſolid Globes in moving through the Air, are reſiſted in that Proportion.

Experiment 1. Three Cylindrical Pipes, whoſe Lengths were two, four, and eight Feet, and whoſe common Diameter was $\frac{345}{1000}$ parts of an Inch, were one after another ſcrewed into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and were laid parallel to the Horizon. Theſe three Pipes thus ſituated, diſcharged 175, 133, and $97\frac{1}{2}$ *Troy* Ounces of Water in half a Minute. The Pipes having equal Diameters, the Velocities of the Water flowing through them were

as

as the Quantities of Water discharged in equal Times; that is, as the Numbers 175, 133, and $97\frac{1}{2}$: For when D is given, V is as M. By the other Measure of the Velocity deduced from this *Proposition*, the Velocities ought to have been reciprocally as the Square Roots of the Lengths of the Pipes; that is, nearly as the Numbers 20000, 14142, and 10000. For the Pipes having equal Diameters, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and all laid parallel to the Horizon; D and H were given, and S was 0; and consequently the Velocity, which by this *Proposition* is as $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$, ought in the present Case to have been as $\frac{1}{\sqrt{L}}$. The Velocities from this Measure are nearly proporti-

onal

onal to thoſe from Experiments. Thoſe from Experiments with reſpect to theſe, are as the Numbers 175, 188, 195: whence it appears, that the Velocity from Experiment, with reſpect to the Velocity expreſſed by the other Meaſure, is ſomething greater in the longer of any two of theſe Pipes than in the ſhorter; as it ought to be, from what has been ſaid, both on account of the Reſiſtance of the Air, and the Nature of the moving Force.

Experiment 2. Three Cylindrical Pipes of equal Lengths, whoſe Diameters were $\frac{372}{1000}$, $\frac{185}{1000}$, and $\frac{90}{1000}$ parts of an Inch, were one after another ſcrew'd into the Side of the Veſſel, at the perpendicular Diſtance of four Feet from the Top of the Water, and were laid parallel to the Horizon. Theſe Pipes thus ſituated diſcharged 179, $33\frac{1}{2}$, and $6\frac{1}{8}$ Ounces of Water in half a Minute. The Velo-

Velocities, found by dividing theſe Quantities by the Squares of the Diameters of their reſpective Pipes, were as the Numbers 1293, 1008, and 756. By the other Meaſure they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 193, 136, and 94. For the Pipes having equal Lengths, being all inſerted into the Side of the Veſſel, at the ſame perpendicular Diſtance from the Top of the Water, and being laid parallel to the Horizon; L and H were given, and S was o; and conſequently $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ was in this Caſe as $\sqrt{D}$. The Velocities from this Meaſure are nearly proportional to thoſe from Experiments. Thoſe from Experiments, with reſpect to theſe, are as the Numbers 670, 741, 804; whence it appears, that the Velocity from Expe-

Experiment, with reſpect to what it ought to be by the Meaſure of this *Propoſition*, is ſomething greater in the narrower of any two of theſe Pipes than in the wider; as I have ſhewn it ought to be, from the Nature of the moving Force.

Experiment 3. Two Cylindrical Pipes, whoſe Lengths were eight Feet and two Feet, and whoſe Diameters were $\frac{345}{1000}$ and $\frac{185}{1000}$ parts of an Inch, were ſcrew'd into the Side of the Veſſel at the perpendicular Diſtances of four Feet, and one Foot from the Top of the Water, and were laid parallel to the Horizon. Theſe Pipes thus fixed diſcharged $87\frac{1}{2}$, and 16 Ounces of Water in half a Minute. The Velocities in them, found by dividing their Diſcharges by the Squares of their Diameters, were nearly as the Numbers 73, and 46. By the other Meaſure of the Velocity they ought to have been

as

as the Square Root of the Diameters of the Pipes; that is, nearly as the Numbers 186 and 134: For H and L were each of them 4 in the firſt Experiment, and 1 in the ſecond, and S was nothing in both; and conſequently the Velocity expreſſed by $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$, in the preſent Caſe, was as $\sqrt{D}$. The Velocity in the Pipe which was nearer to the Top of the Veſſel, was leſs than it ought to have been by this Meaſure, in the Proportion of 34 to 39. And in all the Experiments I have made upon this Occaſion, I have always found the Velocities in the ſame Pipes placed at different Diſtances from the Top of the Water, to be leſs at leſs Diſtances from the Surface than at greater with reſpect to what they ought to have been by this *Propoſition*. This may be owing, partly to a Diſturbance given to the Motion by the Water which was poured in at the Top of the Veſſel in order to keep it conſtantly full; which Diſturbance being greater at a leſs Diſtance from the Surface, might cauſe a greater Loſs of Motion: and partly to the moving Force's being in reality ſomething greater at a greater Diſtance from the Top of the Water, than it ought to be by the Meaſure I have given of it.

Experiment 4. Two Cylindrical Pipes of equal Diameters, and of the Lengths 1 and 4, were one after the other ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and were each of them depreſſed in an Angle of 30 Degrees below the Plane of the Horizon. Theſe Pipes thus ſituated diſcharged $41\frac{3}{8}$ and $25\frac{5}{8}$ Ounces of

Water in half a Minute. The Velocities in theſe Pipes, on account of their having equal Diameters, were as the Quantities diſcharged. By the other Meaſure they ought to have been as the Numbers 300 and 173; for D was given becauſe the Pipes had equal Diameters, and being both depreſſed below the Horizon; the Meaſure of the Velocity $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ in this Caſe became $\sqrt{\frac{H+S}{L}}$. The natural Sine of 30 Degrees being equal to half the Radius, S was half a Foot for the ſhorter Pipe, and two Feet for the longer; and H + S was $4\frac{1}{2}$ for the firſt, and $\frac{6}{4}$ or $\frac{3}{2}$ for the ſecond; or 9 for the firſt, and 3 for the ſecond. But the Square Roots of 9 and 3 are as the Numbers 300 and 173, which Numbers are nearly in the ſame Proportion as the Numbers

$41\frac{3}{8}$, and $25\frac{3}{8}$; and therefore the Velocities were nearly in the ſame Proportion as they ought to have been by this *Propoſition*.

Propoſition II.

IF a Fluid flow thro' two Syſtems of Cylindrical Pipes made of a given Sort of Matter, and conſiſting each of one Trunk, and the ſame Number of Branches ariſing from it; if the Pipes of the two Syſtems have like Situations and Capacities, that is, if any two correſponding Pipes be ſimilarly ſituated with reſpect to the reſt of the Pipes, and their Capacities be as the Capacities of the whole Syſtems; And if the Forces generating the Motions in two correſponding Pipes be in the ſame Proportion as the whole moving Forces of the two Syſtems: The Velocities in the two correſponding Pipes, ſetting aſide the Reſiſtance of

the

the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Syſtems directly, and the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly. If V, v *be put for the Velocities in the two Pipes;* D, d, *and* L, l *for their Diameters and Lengths; and* F, f *for the whole moving Forces of the two Syſtems; I ſay, that* $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$.

For by the *Firſt Propoſition*, the Velocities in two correſponding Pipes of the two Syſtems, ſetting aſide the Reſiſtance of the Air, are in Ratios compounded of the ſubduplicate Ratios of the Forces generating the Motions in the two Pipes directly, and the ſubduplicate Ratios of the Diameters and Lengths of the Pipes inverſly: But by Suppoſition the Forces generating

nerating the Motions in the two Pipes are in the ſame Proportion as the whole moving Forces of the two Syſtems, and the Capacities of the two Pipes are as the Capacities of the two Syſtems: And therefore by Proportion of Equality, the Velocities in the two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Syſtems directly, and the ſubduplicate Ratios of the Diameters and Lengths of the two Pipes inverſly.

PROOF *by* EXPERIMENTS.

Experiment I.

I Had two Syſtems of Cylindrical Pipes made of Braſs, each of which conſiſted of a Trunk and two Branches.

Branches. The larger Branch of each Syſtem was a Continuation of its Trunk, having an equal Diameter, and lying in a right Line with it; and the ſmaller Branch of each made an Angle of 30 Degrees with the larger. The Trunks and Branches of the two Syſtems were each of them one Foot in Length; the Diameter of the Trunk and larger Branch in the greater Syſtem was $\frac{345}{1000}$, and the Diameter of the ſmaller Branch $\frac{187}{1000}$ parts of an Inch; and the Diameter of the Trunk and larger Branch in the leſſer Syſtem was $\frac{187}{1000}$, and the Diameter of the ſmaller Branch $\frac{90}{1000}$ parts of an Inch. The Trunks of the two Syſtems were ſucceſſively ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon. In this Situation, the

Branches

Branches of the greater Syſtem diſcharged 169½ and 20, and the Branches of the leſſer 30¼ and 4 Ounces of Water in half a Minute. The Velocities in the Trunks and Branches of theſe Syſtems, found by dividing the Quantities which flow'd through them in a given Time by the Squares of their reſpective Diameters, were as the Numbers 1592, 1424, and 571 in the Trunk and Branches of the greater Syſtem; and as the Numbers 979, 865, and 500 in the Trunk and Branches of the leſſer. The Quantities of Water contained in theſe two Syſtems, were as the Numbers 273 and 78; as I found by multiplying the Squares of the Diameters of the ſeveral Pipes into their Lengths, and then adding the Products of each Syſtem into one Sum. Since all the Pipes of the two Syſtems were at the ſame perpendicular Diſtance from the Top of of the Water, and lay parallel to the Horizon, in which Poſition the Weights of Fluid contained in the Pipes made no part of the Forces generating the Motions of the Water flowing thro' them, the Forces generating the Motions in the Trunks and correſponding Branches, were as the Squares of their Diameters, or as the Quantities of Water contained in them, becauſe they all had the ſame Length. And therefore had theſe two Syſtems been truly made, ſo as to have had the Conditions required in the *Propoſition*, that is, had the Quantities of Water contained in the Trunks and correſponding Branches been exactly proportional to the whole Quantities of Water contained in the two Syſtems; the Velocities in thoſe Pipes, ſetting aſide the Reſiſtance of the Air, ought to have been in the ſubduplicate Ratios of their

Diameters directly. But the Capacity of the lesser Branch of the greater System compared with the Capacity of that System, was greater than the Capacity of the lesser Branch of the lesser System compared with the Capacity of its System, in the Proportion of 128 to 103. The Velocity by Experiment in the lesser Branch of the greater System compared with the Velocity by the Theory, was less than it would have been had the Branch been truly constructed; which agrees with what I have already shewn both from Experiments and Reason, namely, that in Pipes of different Diameters but equal Lengths the Velocity by Experiment compared with the Velocity by the Theory, is always greatest in the narrowest Pipes. The Velocity by Experiment with respect to the Velocity measured by the Square Root

Root of the Diameter of the Pipe, was leſs in the ſmaller Branch of the greater Syſtem than in the ſmaller Branch of the leſſer Syſtem, in the Proportion of 21 to 26. As the Capacity of the ſmaller Branch with reſpect to the Capacity of the Syſtem, was ſomething greater in the greater Syſtem than in the leſſer; ſo the Capacity of the Trunk or larger Branch with reſpect to the Capacity of the Syſtem, was on the contrary ſomething leſs in the greater Syſtem than in the leſſer; and by Conſequence, from what has been ſaid concerning the Nature of the moving Force, the Velocity by Experiment with reſpect to the Velocity meaſured by the Square Root of the Diameter of the Pipe, was greater in the Trunk and larger Branch of the greater Syſtem than it was in the Trunk and larger Branch of the leſſer: In the

Trunk it was greater in the Proportion of 86 to 72, and in the Branch it was greater in the Proportion of 76 to 63. These Deviations of the Theory from Experiments, are not Objections against it, but rather Arguments of its Truth; since they all arise, and may be accounted for, from the Systems not having exactly the Conditions required in this *Proposition*.

Experiment II. Two Systems of Cylindrical Pipes, the lesser of which was the greater of the two Systems used in the last Experiment, and the greater a System four times as great, its Trunk and Branches having the same Diameters, and being four times as long as the Trunk and Branches of the lesser, had their Trunks successively screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and had both their Trunks and

and Branches laid parallel to the Horizon: In this Poſition the Branches of the greater Syſtem diſcharged 90¾, and 13½; and the Branches of the leſſer 169½, and 20 Ounces of Water in half a Minute. The Diameters of the Trunks and correſponding Branches of the two Syſtems being equal; the Velocities in thoſe Pipes were as the Quantities of Water which flow'd thro' them in a given Time, that is, as the Numbers 104¼, 90¾, 13½ in the Trunk and Branches of the greater Syſtem; and as the Numbers 189½, 169½, 20 in the Trunk and Branches of the leſſer. The Diameters of the correſponding Pipes of the two Syſtems being equal, the Pipes lying parallel to the Horizon, and at the ſame perpendicular Diſtance from the Top of the Water; the moving Forces of the two Syſtems were equal, as were the moving

ving Forces of any two of their correſponding Pipes; and the Quantities of Water contained in the Syſtems were as the Quantities contained in their Trunks, or in any two of their correſponding Branches, which Quantities were as the Lengths of thoſe Pipes, their Diameters being equal; and therefore by this *Propoſition*, the Velocities in the correſponding Pipes of the Syſtems ought to have been in the ſubduplicate Ratios of the Lengths of thoſe Pipes, that is, they ought to have been twice as great in the Trunk and Branches of the ſhorter Syſtem as in the Trunk and correſponding Branches of the longer, as they nearly were; only they were ſomething greater than they ought to have been in the longer Syſtem, from a leſs Reſiſtance of the Air, and from the Nature of the moving Force, which from what has been

been ſaid concerning its Meaſure, was ſomething greater in the longer Syſtem than in the ſhorter.

Experiment III. I placed the two Syſtems, uſed in the laſt Experiment, at different perpendicular Diſtances from the Top of the Water with their Trunks and Branches parallel to the Horizon; and always found the Velocities in the Trunk and Branches of each Syſtem to be nearly in the ſubduplicate Ratios of the perpendicular Diſtances of the Syſtem from the Top of the Water; only at leſs Diſtances they were ſomething leſs than they ought to have been by this Meaſure, for the Reaſons aſſigned in the third Experiment of the firſt *Propoſition*.

Experiment IV. The two Syſtems uſed in the ſecond and third Experiments, were one after the other ſcrew'd into the Side of the Veſſel at different perpendicular Diſtances

from

from the Top of the Water, the leſſer at the Diſtance of one Foot, and the greater at the Diſtance of four Feet, and were turned till the leſſer Branch of each Syſtem was depreſſed in an Angle of 30 Degrees below the Plane of the Horizon, while the Trunk and larger Branch of each Syſtem lay parallel to it: The Syſtems being thus ſituated, the Branches of the greater Syſtem diſcharged $89\frac{1}{2}$, $17\frac{1}{2}$; and the Branches of the leſſer 79, $13\frac{1}{4}$ Ounces of Water in half a Minute. The Diameters of the correſponding Pipes being equal; the Velocities in them were as the Quantities of Water which flowed through them in the given Time of the Motion, that is, as $206\frac{5}{8}$, $89\frac{1}{2}$, $17\frac{1}{3}$ in the Trunk and Branches of the greater Syſtem; and as $92\frac{1}{4}$, 79, $13\frac{1}{4}$ in the Trunk and Branches of the leſſer. The Diameters of the correſponding Pipes being equal,

and

and the Forces generating the Motions in thoſe Pipes being nearly proportional to the Quantities of Water contained in them, and the whole moving Forces of the two Syſtems being nearly proportional to their whole Quantities of Fluid; the Velocities in the correſponding Pipes ought to have been equal by this *Propoſition*. The Differences were not great, and probably aroſe chiefly from the leſſer Syſtem being placed nearer to the Top of the Water than the greater.

Propoſition III.

IF a Fluid flow thro' two Syſtems of Cylindrical Pipes made of a given Sort of Matter, and conſiſting each of two Trunks, and the ſame Number of Branches ſimilar in their Situations and Capacities, that is, if

any

any two correſponding Pipes be ſimilarly ſituated with reſpect to the reſt of the Pipes, and their Capacities be as the Capacities of their whole Syſtems, if in each Syſtem the laſt and ſmalleſt Branches of the two Trunks be continuous, and if the Forces generating the Motions in any two correſponding Pipes be in the ſame Proportion as the whole moving Forces of the two Syſtems; The Velocities in two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Syſtems directly, and the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly, that is, $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$.

For by the *Firſt Propoſition*, the Velocities in two correſponding Pipes

Pipes of the two Syſtems, ſetting aſide the Reſiſtance of the Air, are in Ratios compounded of the ſubduplicate Ratios of the Forces generating the Motions in the two Pipes directly, and the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly: But by Suppoſition, the Forces generating the Motions in two correſponding Pipes, are as the whole moving Forces of the two Syſtems, and the Capacities of two correſponding Pipes, as the whole Capacities of the two Syſtems: And therefore by Proportion of Equality, the Velocities in two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Syſtems directly, and the ſubduplicate Ratios of the Diameters and Lengths of the two Pipes taken together inversly.

PROOF *by* EXPERIMENTS.

TO examine the Truth of this *Proposition* by Experiments, I got made of Brass two such Systems of Cylindrical Pipes as are represented in these Figures. Each System consisted of two Trunks and five Branches all lying in one and the same Plane. The Trunks and Branches of each had equal Diameters and Lengths. The common Diameter of the Trunks and Branches of the greater System, was $\frac{187}{1000}$; and the common Diameter of the Trunks and Branches of the lesser System, was $\frac{90}{1000}$ parts of an Inch. The common Length of the Trunks and Branches of the greater System, was half a Foot; and the common Length

Length of the Trunks and Branches of the leſſer, three Inches. The Trunks of each Syſtem opened into the Branches, through two triangular Spaces which were each three Inches long in the greater Syſtem and an Inch and a half in the leſſer; and their Capacities were nearly in the ſame Proportion as the Capacities of their Trunks or Branches, that is, in the Proportion of 87 to 10. When the Ends F and f were ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon; their other Ends G and g diſcharged $36\frac{5}{8}$ and $8\frac{1}{8}$ Ounces of Water in half a Minute. The Velocities in the Trunks, found by dividing the Diſcharges by the Squares of their Diameters, were as the Numbers 26 and 25 nearly. And the Veloci-

ties

ties by this *Proposition* ought to have been as the Numbers 96½ and 95, which are proportional to the Numbers 26 and 25 very nearly. And since the Systems were similar, and similarly situated, no Doubt can be made, but that the Velocities in corresponding Branches were likewise in the same Proportion.

Proposition IV.

IF a Fluid flow thro' two compounded Systems of Cylindrical Pipes, consisting each of two Cylindrical Trunks, and the same Number of smaller Systems, like those described in the last Proposition, *the Trunks of which smaller Systems open into their respective principal Trunks of the compounded Systems, if all the corresponding Pipes of the compounded Systems have like Situations and Capacities, that is, if any two*

two correſponding Pipes be ſimilarly ſituated with reſpect to the reſt of the Pipes, and their Capacities be in the ſame Proportion as the whole Capacities of the compounded Syſtems, and if the Forces generating the Motions in two correſponding Pipes be as the whole moving Forces of the two compounded Syſtems; the Velocities in two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two compounded Syſtems directly, and the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly, that is, $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$.

The Demonſtration of this *Propoſition* is the ſame with that of the laſt, and therefore need not be repeated.

Cor.

Cor. 1. If the whole moving Forces of the two compounded Syſtems be as the Capacities of the Syſtems, and conſequently as the Capacities of two correſponding Pipes; the Velocities in thoſe Pipes, ſetting aſide the Reſiſtance of the Air, will be in the ſubduplicate Ratios of the Diameters of the Pipes. If $F.f :: D^2 L. d^2 l$; then will $V.v :: \sqrt{D}.\sqrt{d}$.

Cor. 2. If the whole moving Forces of the two compounded Syſtems be as the Capacities of the Syſtems, and conſequently as the Capacities of two correſponding Pipes, and the Diameters of the correſponding Pipes be in the ſubduplicate Ratios of their Lengths, or of the Lengths of the Syſtems; the Velocities in correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in the ſubquadruplicate Ratios of the Lengths of the Syſtems. If

F.

$F . f :: D^2 L . d^2 l$, and $D . d :: \sqrt{L} . \sqrt{l}$; then will $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$.

Cor. 3. If the whole moving Forces of the two compounded Syſtems be as the m Power of the Capacities of the Syſtems, and conſequently as the m Power of the Capacities of two correſponding Pipes, and the Diameters of the Pipes be as the n Power of their Lengths, or as the n Power of the Lengths of the Syſtems; the Velocities in two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in the $\frac{2nm+m-n-1}{2}$ Power of the Lengths of the Syſtems. If $F . f :: D^2 L^m . d^2 l^m$, and $D . d :: L^n . l^n$; then will $V . v :: L^{\frac{2nm+m-n-1}{2}} . l^{\frac{2nm+m-n-1}{2}}$.

Cor. 4. The whole moving Forces of the two compounded Syſtems are in Ratios compounded of the duplicate Ratios of the Velocities in two correſponding Pipes, and the ſimple Ratios of their Diameters and Lengths, that is, F . f :: V^2 D L. v^2 d l.

Scholium.

This *Propoſition* will hold true, if the two Syſtems be made of Conical Pipes equal in their Capacities and Lengths to the Cylindrical ones, and ſo conſtructed, as that the greateſt or leaſt Diameters of two correſponding Conical Pipes ſhall every where bear the ſame Proportion to each other, as the Diameters of the two Cylindrical Pipes which are equal to them.

Pro-

Propofition V. Problem I.

THE Velocity of a Fluid moving through a Cylindrical Pipe of a given Diameter and Length and the Force *generating the Motion being given; to determine the Velocities generated by an equal* Force *in the feveral Parts of a Syftem like one of the Syftems defcribed in the* Third Propofition, *which Syftem confifts of two given Cylindrical* Trunks *and a given Number of Cylindrical Branches into which the two Trunks open.*

The two Forces generating the Motions in the Cylindrical Pipe and in this Syftem being equal by Suppofition; their Meafures will likewife be equal, which Meafures may be had from *Cor. 7. Prop.* I. For the Force generating the whole Motion of the Syſtem, is the Sum of the Forces generating the Motions in all its Parts; and the Meaſures of the Forces generating the Motions in the ſeveral Parts of the Syſtem, may be expreſſed by that *Corollary*. Putting L for the Length of the Cylindrical Pipe, D for its Diameter, V for the Velocity of the Fluid moving through it; l for the Length of that Trunk through which the Fluid flows into the Syſtem, d for its Diameter, and x for the Velocity of the Fluid flowing through it; Λ for the mean Length of the Branches, Δ for the Diameter of a Cylinder whoſe Length is that mean Length, and whoſe Orifice is equal to the Sum of the Orifices of all the Branches; λ for the Length of the other Cylindrical Trunk; and δ for its Diameter: the Meaſure of the Force generating the Motion of the Fluid flowing thro' the Cylindrical Pipe

Pipe is $V^2 D L$; and the Meaſure of the Force generating the Motion in that Trunk through which the Fluid flows into the Syſtem is $x^2 d l$: The mean Velocity in the Branches, is to x the Velocity in that Trunk, as d^2, is to Δ^2, becauſe the Velocities of the ſame Quantity of Fluid flowing through two Cylindrical Pipes in the ſame time, are reciprocally proportional to the Squares of their Diameters; whence the mean Velocity in the Branches is $\frac{x d^2}{\Delta^2}$; and the Meaſure of the Force generating the Motion in the Branches taken all together, is $\frac{x^2 d^4 \Lambda}{\Delta^3}$: By the ſame Reaſoning the Velocity in the other Trunk thro' which the Fluid flows out of the Syſtem, is $\frac{x d^2}{\delta^2}$; and the Meaſure of the Force generating the Motion of the Water flowing thro'

thro' it, is $\frac{x^2 d^4 \lambda}{\delta^3}$: But the Sum of the Forces generating the Motions in all the Parts of the Syſtem, is by Suppoſition equal to the Force generating the Motion in the Cylindrical Pipe; and by Conſequence, $x^2 d l + \frac{x^2 d^4 \Lambda}{\Delta^3} + \frac{x^2 d^4 \lambda}{\delta^3} = V^2 D L$, whence x is equal to $\sqrt{\frac{V^2 D L}{d l + \frac{d^4 \Lambda}{\Delta^3} + \frac{d^4 \lambda}{\delta^3}}}$.

If this Value of x be ſubſtituted in its Room in $\frac{x d^2}{\Delta^2}$, the Meaſure of the mean Velocity in the Branches; that Meaſure will become $\frac{d^2}{\Delta^2}$ $\sqrt{\frac{V^2 D L}{d l + \frac{d^4 \Lambda}{\Delta^3} + \frac{d^4 \lambda}{\delta^3}}}$.

If the ſaid Value of x be ſubſtituted in its Room in $\frac{x d^2}{\delta^2}$, the Meaſure of the Velocity in the other Trunk;

Trunk; that Meaſure will become
$$\frac{d^2}{\delta^2}\sqrt{\frac{V^2DL}{dl+\frac{d^4\Lambda}{\Delta^3}+\frac{d^4\lambda}{\delta^3}}}.$$

Cor. 1. If the Capacity of the Branches be enlarged by an Enlargement of their Diameters or an Encreaſe of their Number, that is, if Δ be encreaſed, all other Things continuing the ſame; the Velocities generated by a given Force, will be greater in the Trunks and leſs in the Branches than they were before this Change happened in the Capacity of the Branches.

Cor. 2. If the Capacity of the Branches be leſſened by a Contraction of their Diameters or a Decreaſe of their Number, that is, if Δ be diminiſhed, all other Things continuing the ſame; the Velocities generated by a given Force, will be leſs in the Trunks and greater

in

in the Branches than they were before this Change was made in the Capacity of the Branches.

Cor. 3. If the two Trunks of the Syſtem be given; the Velocities generated by a given Force, will be greateſt in the Trunks and leaſt in the Branches when Δ is infinite, in which Caſe the Term $\frac{d^4\lambda}{\Delta^3}$ will vaniſh or become nothing: The Velocity in the Trunk through which the Fluid flows into the Syſtem will be $\sqrt{\frac{V^2DL}{dl+\frac{d^4\lambda}{\delta^3}}}$: The Velocity in the Branches will be infinitely little: And the Velocity in the other Trunk will be $\frac{d^2}{\delta^2}\sqrt{\frac{V^2DL}{dl+\frac{d^4\lambda}{\delta^3}}}$.

Cor. 4. If the Velocity in the given Cylindrical Pipe be equal to the

the Velocity in that Trunk thro' which the Fluid flows into the Syſtem, that is, if V be equal to x, and conſequently V^2 equal to x^2, and if the Diameter of the given Cylindrical Pipe, be equal to the Diameter of that Trunk through which the Fluid flows into the Syſtem, that is, if D be equal to d; then the Length of the Cylindrical Pipe or L, will be equal to $l + \frac{d^3 \Lambda}{\Delta^3} + \frac{d^3 \lambda}{\delta^3}$.

Cor. 5. If the Branches taken together, be wider than either of the Trunks; the mean Velocity in them will be leſs than it is in the Trunks: and if one Trunk be wider than the other; the Velocity will be as much leſs as the Trunk is wider.

PROOF *by* EXPERIMENTS.

THE greater of the Syſtems which were made for the Proof of the *Third Propoſition*, was ſcrewed into the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and was turned till its Branches were parallel to the Horizon. The Branches of this Syſtem were ſo contrived, that their Ends next to the Veſſel could be opened or ſhut by little Braſs Sliders fixed to the Plate thro' which thoſe Pipes paſſed, which Sliders being moved up or down, opened or ſhut the Ends of the Branches. This Syſtem being thus ſituated, when the Branch C only was open; the Trunk G diſcharged 29½ Ounces of Water in half a Minute;

nute: When the three Branches b, c, d were open, it diſcharged 36 Ounces: And when all the five Branches were open, it diſcharged $36\frac{5}{8}$ Ounces in the ſame Time. The Velocities in the two equal Trunks, were as the Quantities diſcharged. When one Branch only was open, the Velocity in that Branch, was equal to the Velocity in the Trunk; and therefore the Velocity in the Branch C, when the reſt of the Branches were ſhut, was as $29\frac{1}{2}$. The mean Velocity in the three Branches, found by applying 36 to 3 the Sum of their Orifices, the Orifice of each of the Trunks being 1, was as 12: and the Velocity in the five Branches, when they were all open, found by dividing $36\frac{5}{8}$ by 5, was as $7\frac{13}{40}$. Theſe were the true Velocities in the Trunks and Branches in theſe three Experiments. I ſhall now ſhew what they ought to have been by this Problem.

The two Trunks and Branch C taken together, may be conſidered as one Cylindrical Pipe; and therefore may repreſent the given Cylindrical Pipe in this Problem, in which the Velocity V is as $29\frac{1}{2}$. The Trunks and Branches of this Syſtem having all equal Diameters, D, d, and δ were equal. The Lengths of the two Trunks were equal, and when added together, their Sum was equal to the Length of the Branches added to the Lengths of the two triangular Spaces into which they opened; therefore l was equal to λ, and $l + \lambda$ equal to Λ if the triangular Spaces be conſidered as Parts of the Branches, on which Suppoſition L was equal to $l + \lambda + \Lambda$; and by Conſequence equal to two Feet; for l and λ were each half a Foot, and Λ one Foot. The Velo-

city

city in the Trunks, d being 1, will be expreſſed by $\sqrt{\frac{1740\frac{1}{2}}{1+\frac{1}{\Delta^3}}}$; there-fore when three Branches were o-pen, and by Conſequence Δ equal to $\sqrt{3}$; the Velocity ought to have been nearly as 38: And nearly as 40; when all five were open, and Δ equal to $\sqrt{5}$.

The Velocities in the Branches, expreſſed by $\frac{d^2}{\Delta^2}\sqrt{\frac{1740\frac{1}{2}}{1+\frac{1}{\Delta^3}}}$, ought to have been $12\frac{2}{3}$, when three Branches were open; and 8, when all five were open. The near Agreement of theſe Velocities with thoſe from Experi-ments, ſhews the Velocities in the Trunks and Branches of this Syſtem to be rightly determined by this Problem.

Pro-

Propoſition VI.

I F *a Fluid flow through a ſimple Syſtem of Cylindrical Pipes, conſiſting of one Trunk and a certain Number of Branches; the Velocity in any Pipe will be greater or leſs, as the moving Force of the Syſtem is greater or leſs, as the Pipe is wider or narrower, ſhorter or longer, nearer to or farther from the moving Force, as the Weight of Fluid in the Pipe conſpires with or oppoſes its Motion, or as any of the other Pipes of the Syſtem is lengthened or ſhortened.*

That the Velocity in any Pipe of this Syſtem is greater or leſs, as the moving Force of the Syſtem is greater or leſs, as the Pipe is wider or narrower, ſhorter or longer, or as the Weight of Fluid contained in the

the Pipe conſpires with or oppoſes its Motion; has been fully proved in the foregoing *Propoſitions*. And that the Velocity is greater or leſs, as the Pipe is nearer to or farther from the moving Force, may be thus proved. From the Nature of this Motion, the whole moving Force is reſiſted by the Quantity of Fluid contained in the whole Syſtem: And that part of this Force which moves the Fluid through any Pipe, is reſiſted by the Quantity of Fluid in that part of the Syſtem which lies before it; the Reſiſtance therefore will be greater or leſs, as a Pipe is nearer to or farther from the moving Force: But as the Reſiſtance is greater or leſs, the Preſſure of the moving Fluid againſt the Orifice of the Pipe, and conſequently the Velocity in the Pipe, is greater or leſs; and therefore, *cæteris paribus*, the Velocity in a Pipe is greater

greater or leſs, as it is nearer to or farther from the moving Force. Laſtly, the Velocity in a Pipe will be greater or leſs, *cæteris paribus*, as any of the other Pipes of the Syſtem is lengthened or ſhortened: For by lengthening or ſhortening a Pipe, the Reſiſtance given by the Fluid contained in it to that part of the moving Force of the Syſtem which is ſpent on that Pipe, becomes greater or leſs than it was before: But a greater or leſs Reſiſtance makes the moving Force to act more or leſs powerfully on the other Pipes, and encreaſes or leſſens the Velocities in them: And therefore the Velocity in a Pipe will be encreaſed or leſſened, *cæteris paribus*, as any of the other Pipes is lengthened or ſhortened.

PROOF *by* EXPERIMENTS.

THAT the Velocity in a Pipe of this Syſtem is greater or leſs, as the moving Force of the Syſtem is greater or leſs, or as the Weight of Fluid contained in it conſpires with or oppoſes its Motion, as the Pipe is wider or narrower, ſhorter or longer, is fully proved by the Experiments of the foregoing *Propoſitions*. And that the Velocity is greater or leſs as the Pipe is nearer to or farther from the moving Force, or as any other Pipe of the Syſtem is lengthened or ſhortened, will appear from the following Experiments.

A Syſtem of Cylindrical Pipes conſiſted of a Trunk, and three Branches of equal Diameters and Lengths; the Branches lay all in the ſame Plane, and were placed at the Diſtances of four, nine, and ſixteen Feet from the moving Force of the Syſtem, or that End of the Trunk which was ſcrewed into the Side of the Veſſel. The Branches, beginning with that which lay neareſt to the moving Force, diſcharged in the ſame Time Quantities of Water, which were as the Numbers 9, 6, and 5. The Branches having equal Diameters, the Velocities in them were as the Quantities diſcharged; and therefore, the Velocity in a Pipe is greater or leſs, *cæteris paribus*, as the Pipe is nearer to or farther from the moving Force.

A given Branch at the Diſtance of one Foot from the moving Force diſcharged 20 Ounces of Water in half a Minute, when the Length of the Trunk was two Feet; and 36 Ounces in the ſame Time, when the Length

Length of the Trunk was encreaſed to eight Feet. And the ſame Change of Velocity, but in a leſs Degree, was produced by lengthening any of the other Branches; and therefore, the Velocity in a given Pipe will be greater or leſs, *cæteris paribus*, as any of the other Pipes of the Syſtem is lengthened or ſhortened.

Propoſition VII.

If a Fluid flow through a ſimple Syſtem of Cylindrical Pipes, conſiſting of one Trunk and a certain Number of Branches; and if any Pipe of the Syſtem be obſtructed or opened, contracted or dilated; the Velocity will be encreaſed or diminiſhed in all the other Pipes of the Syſtem: And the Increaſe or Diminution of Velocity in any one of them,

them, will be greater or leſs, cæteris paribus, *as the Pipe is nearer to or farther from the obſtructed or opened, contracted or dilated Pipe.*

Since to obſtruct or contract a Pipe, is in Effect to lengthen it; and to open or dilate it, is in Effect to ſhorten it; the firſt part of this *Propoſition,* is true by the laſt *Propoſition:* And the ſecond part of it is thus proved. When a Pipe is obſtructed or contracted, that part of the moving Force which before this Change generated the Motion deſtroyed in the obſtructed or contracted Pipe, is not loſt, but ſpent in increaſing the Motions in the other Pipes which are open, and may be conſidered as a new Force apply'd to the Syſtem at the Place of Obſtruction or Contraction, and propagated from thence to all the other Pipes of the Syſtem; and there-

therefore, by the laſt *Propoſition*, the Velocities generated in thoſe Pipes by this new Force, will be greater or leſs, as the Pipes are nearer to or farther from the Force, that is, as they are nearer to or farther from the Place of Obſtruction or Contraction. And the contrary muſt happen, when a Pipe is opened or dilated; the Velocities will then be diminiſhed in all the other Pipes, and its Diminution will be greater or leſs, *cæteris paribus*, as the Pipes are nearer to or farther from the Place of Aperture or Dilatation: And therefore the *Propoſition* is true.

Cor. If the ſimple Syſtem be ſo conſtructed, that the Velocities in its Trunk and Branches be reſpectively equal to the Velocities in that principal and thoſe leſſer Trunks of ſuch a compounded Syſtem of Cylindrical Pipes as I have deſcribed in the fourth *Propoſition* and

and its *Scholium*, through which Trunks the Fluid flows into the compounded Syſtem and leſſer Syſtems of which it is compoſed; then, whatever Change is made in the Velocities of two correſponding Pipes of the two Syſtems, that Change will produce like Changes of Velocity in all the other correſponding Pipes; and by Conſequence, when the Velocity is leſſened in any one of the ſaid leſſer Trunks of the compounded Syſtem; it will be increaſed in all the others, and its Increaſe will be greater or leſs, *cæteris paribus*, as the Trunks are nearer to or farther from that in which the Velocity is leſſened: And when the Velocity is increaſed in one of the ſaid leſſer Trunks, it will be leſſened in all the reſt: And its Diminution will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from that

that Trunk in which the Velocity is increaſed.

PROOF *by* EXPERIMENTS.

A Syſtem of Cylindrical Pipes had five Branches, A, B, C, D, E, of equal Diameters and Lengths. The Branch A lay neareſt to the moving Force, then B, and ſo on in the Order they are mentioned. The Velocities in theſe Branches, obtained from the Quantities of Water diſcharged in a given Time, were as the Numbers $94\frac{2}{3}$, 68, 52, $36\frac{1}{3}$, $19\frac{1}{7}$, when the End of the Trunk was open; and as the Numbers 98, $76\frac{1}{4}$, $70\frac{1}{2}$, $66\frac{1}{2}$, $61\frac{1}{6}$, when the End of the Trunk was ſhut; and the Differences of the Velocities in the ſame Pipes, when the End of the Trunk was open and ſhut, were $3\frac{1}{2}$, $8\frac{1}{4}$, $18\frac{1}{2}$, $30\frac{1}{6}$, $42\frac{1}{42}$.

$42\frac{1}{42}$. When the Branch C was ſhut, the Velocities in the Branches A, B, D, E, were as the Numbers $99\frac{1}{2}$, $81\frac{1}{2}$, $43\frac{3}{4}$, $23\frac{1}{3}$; and the Differences of theſe Velocities and the Velocities in the ſame Branches, when C was open, were $4\frac{5}{6}$, $13\frac{1}{2}$, $7\frac{1}{2}$, $4\frac{1}{5}$. And the ſame Changes of Velocity, but in a leſſer Degree, will be produced when a Pipe is only contracted.

If the Syſtem had originally had but the four Branches A, B, D, E, and afterwards the Branch C had been added; it is evident from theſe Experiments, that the Velocities in the original Branches would all have been diminiſhed by the Addition of this new Branch; and that the Diminution of Velocity in any of them would have been greater or leſs, as it lay nearer to or farther from the Branch C: But the adding a new Pipe to a Syſtem, will produce like Changes of Motion in the other Pipes,

Pipes, as the opening or dilating an old Pipe; for by all theſe, there will be a like Abatement of the Force generating the Motion in the other Pipes.

Therefore by theſe Experiments and the *Corollary* of this *Propoſition*, when any Pipe of the ſimple Syſtem, or any of the aforeſaid Trunks of the compounded Syſtem, is obſtructed or opened, contracted or dilated; the Velocity will be encreaſed or diminiſhed in all the other Pipes of the ſimple Syſtem, and all the reſt of the aforeſaid Trunks in the compounded Syſtem; and its Increaſe or Diminution in any one of thoſe Pipes or Trunks, will be greater or leſs, *cæteris paribus*, as it is nearer to or farther from the Pipe or Trunk which is obſtructed or opened, contracted or dilated.

SECTION II.

Of Muſcular Motion, the Motion of the Blood, and Reſpiration.

Of Muſcular Motion.

Propoſition VIII.

MUſcular Motion *is performed by the Vibrations of a very Elaſtick Æther, lodged in the Nerves and Membranes inveſting the minute Fibres of the Muſcles, excited by the Power of the Will, Heat, Wounds, the ſubtile and active Particles of Bodies, and other Cauſes.*

Before I enter upon the Proof of this *Propoſition*, it will be neceſſary to give a ſhort Account of the Structure of a *Muſcle*.

A Muſcle appears to the Eye, to be compoſed of two Parts of different Colours, one red, and the other white. The red is called its fleſhy, and the white its tendinous Part. Some Muſcles are tendinous both at their Origin and Inſertion, and fleſhy only in their Middle; and others are fleſhy at their Origin and in their Middle, and tendinous only at their Inſertion. The fleſhy Part of a Muſcle is compoſed of Fibres, Membranes, Nerves, Blood-Veſſels, and Lympheducts. The Fibres are ſmall Threads, which are ſhortened when a Muſcle is contracted, and lengthened when it is dilated. The Membranes are thin Skins, which run between the Fibres, are faſtened to them, and tye them together. If a Piece of Fleſh be boiled, till it become very tender, and afterwards be divided and ſubdivided, as far as the Eye and Hand can go; it will appear, that each minute Fibre in the loweſt Subdiviſion, is entirely ſurrounded by its own particular Membrane. The Membranes, if they be extremely thin, are tranſparent; and if they be thicker, they are of a whitiſh Colour. The Nerves are diſperſed throughout the whole fleſhy Part, as may be gathered from the Pain which is produced any where in that Part by the ſmalleſt Wound. It has been a received Opinion, that the Nerves are ſmall Pipes which contain a Fluid, called *Animal Spirits*, drawn off from the Blood in the Brain. But it does not appear from any Experiments, that the Nerves are Pipes; or that ſuch a Fluid as they conceive *Animal Spirits* to be, is ſeparated from the Blood in the Brain; and therefore theſe Opinions are without any juſt Foundation. The Nerves are not only impervious

pervious to the ſmalleſt *Stylus*, but when viewed with a Microſcope, evidently appear to have no Cavity. And when we conſider the Manner, in which the Favourers of this Opinion have explained *Muſcular Motion* by *Animal Spirits*; we muſt allow, that ſuch a Fluid is altogether unfit for this Work. For theſe Reaſons, many have thought the Nerves to be ſolid Threads, extended from the Brain to the Muſcles and other Parts of the Body. Sir *Iſaac Newton* is of this Opinion, as appears from the following Account he has given of the Nerves, in the 24th *Query* of his *Opticks*. "I ſuppoſe "that the *Capillamenta* of the "Nerves are each of them ſolid "and uniform, that the vibrating "Motion of the Ætherial Medium "may be propagated along them "from one End to the other uni- "formly, and without Interruption:

"For

" For Obſtructions in the Nerves
" create Palſies. And that they
" may be ſufficiently uniform, I
" ſuppoſe them to be pellucid when
" viewed ſingly, tho' the Reflecti-
" ons in their Cylindrical Surfaces
" may make the whole Nerve
" (compoſed of many *Capillamen-*
" *ta*) appear opake and white. For
" Opacity ariſes from reflecting
" Surfaces, ſuch as may diſturb and
" interrupt the Motions of this Me-
" dium." The Blood-Veſſels of a Muſcle are interwoven in the Membranes, and diſtributed throughout its whole fleſhy Part, as appears from its Redneſs, and from the iſſuing out of Blood from a Puncture made any where in it with the fineſt Needle. The Muſcles are ſtocked with Lymphatick Veſſels, as well as the other Parts of the Body.

I have no farther Occaſion to conſider the Structure of a Muſcle, what

I have ſaid being ſufficient for my Purpoſe, but ſhall now proceed to prove the *Propoſition* from Experiments and Obſervations.

It has been found by Obſervation, that when a Muſcle is contracted, its fleſhy Fibres are ſhortened and hardened, without any ſenſible Change made in its Tendons; that as ſoon as the Contraction is over, or the contracting Force ceaſes to act, the ſhortened and hardened Fibres are lengthened and ſoftened again; that this alternate Motion of Contraction and Dilatation continues in the Hearts of ſome Animals, eſpecially young ones, for a conſiderable Time after they are cut out of their Bodies, and laid on a Table; that it generally continues longer in the Hearts of Fiſh, than in the Hearts of Land-Animals; and that after it has ceaſed, it will be renewed again by Warmth or the pricking

pricking of a Pin, and will continue to be excited by either, eſpecially Warmth, for ſome little time, till the Heart wholly loſes its Power of moving; that as the Heart cools by Degrees, ſo its Motion abates gradually, its Contractions and Dilatations growing leſs and leſs frequent and ſtrong, till at laſt they wholly ceaſe; and that the Heat of the Heart is greater, and its Motion more frequent and ſtrong, in an ardent Fever and the hot Fit of an Ague, than in its natural State.

Hence it appears, that Heat is a remote Cauſe both of the Frequency and Strength of the Motion of the Heart; and conſequently, one of the remote Cauſes of the Motion of a Muſcle.

We find by Experience, that by the Power of the Will we can move the Muſcles of our Limbs with various Degrees of Force; that there

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is not the leaſt ſenſible Difference in point of Time between willing the Motions of the Muſcles, and the Motions themſelves; that Muſcles contracted by the Power of the Will, dilate again the very Inſtant in which the Soul ceaſeth to exerciſe that Power; and that the Soul loſeth the Power of moving the Muſcles, and perceiving Pain from Wounds made in their fleſhy Parts, when their Nerves are cut quite through, tied ſtreight, or intirely obſtructed any other Way.

Hence it appears, that the Nerves are the Inſtruments whereby the Will gives Motion to the Muſcles: And it does this, by producing ſome kind of Motion in thoſe Ends of the Nerves which terminate in the Brain, which Motion is propagated from thence thro' their ſolid, pellucid and uniform *Capillamenta* into the Muſcles. For if the Nerves were intirely at reſt, and no Motion was propagated thro' them, they could never by the Power of the Will, or any other Cauſe, produce Motion in the Muſcles.

On laying bare the great Muſcle of the hinder Leg of a Dog, and the great Nerve which accompanies the Crural Artery and Vein; I have obſerved, that when the Tendon was wounded, the Dog ſhewed very little Uneaſineſs; but expreſſed great Pain, on wounding the fleſhy Part of the Muſcle; and much greater Pain, on wounding, or in the Inſtant of tying the Nerve; that a Contraction of the Muſcle was produced, on wounding its fleſhy Part; and a much ſtronger Contraction on wounding, or in the Inſtant of tying the Nerve; and that after the Nerve was cut quite through, or tied

tied ſtreight, great Uneaſineſs and Pain with moſt violent Struggles were produced, as often as a new Wound was inflicted, or a new Ligature made, above the laſt Section or Ligature, in that Part of the Nerve which communicated with the Brain; but neither Pain nor Contraction of the Muſcle followed, on wounding or tying that Part of it which communicated with the Muſcle and Limb. And I have likewiſe obſerved on trepanning Dogs, and wounding ſeveral parts of their Brains, that convulſive Motions of the Limbs have ever been produced, on wounding the *Medulla oblongata*, but never on wounding the *Dura Mater*, or Cortical Part.

Hence likewiſe it appears, that the Nerves are the principal Inſtruments of Senſation and Motion; that theſe Effects are ſtronger or weaker, as more or fewer of the nervous *Capillamenta* are tyed or wounded; that theſe Effects are the ſame, in whatever part of a Nerve the Section or Ligature is made; and that the Soul perceives Pain, and exerts its Power of producing *Muſcular Motion*, only at the Origin of the Nerves in the Brain.

The exceeding Quickneſs of this Motion paſſing from the Brain thro' the *Capillamenta* of the Nerves to the moſt diſtant Muſcles in an Inſtant, and its Ceſſation the very Moment the Cauſe which produced it ceaſes to act, ſhew it to be the vibrating Motion of a very elaſtick Fluid. For it is the Nature of the vibrating Motion of an elaſtick Fluid to be very ſwift, and to ceaſe the very Inſtant the Cauſe which produced it ceaſes to act. A vibrating Motion excited in our Air by by the Tremors of Bodies for the Production of Sounds, moves at the Rate of 1142 *English* Feet in a second Minute of Time, and ceases the very Instant in which the Tremor of the Bodies cease.

Now since this Motion begun in the Nerves at their Origin, has been proved to be the vibrating Motion of a very elastick Fluid; and since the other Phænomena of Nature absolutely require such an elastick Fluid, as is the Æther described by Sir *Isaac Newton*; and since Causes are not to be multiply'd without Necessity: Therefore it must be granted, that this Motion begun in the Nerves at their Origin, is the vibrating Motion of that Æther; the Properties of which, gathered from the Phænomena, are these which follow.

This Æther is exceedingly more rare and subtile than Air, and ex-

ceed-

ceedingly more elastick and active. It readily pervades all Bodies, and by its elastick Force *is expanded thro' all the* Heavens. *If it be* 700000 *times more elastick than our Air, it is above* 700000 *times more rare. Its elastick* Force *in proportion to its Density, is above* 490000000000 *times greater than the elastick Force of the Air is in Proportion to its Density. It is rarer within Bodies, than in the empty Spaces between them; and in passing from Bodies into empty Spaces, it grows denser and denser by Degrees; and the* Increase *of its Density at any Distance from the Centre of Gravity of a Body, is as the Quantity of Matter in the Body directly, and the Square of that Distance inversly: And it is rarer within dense Bodies, than within rare Bodies. All Bodies endeavour to recede and go from the denser* Parts *of it, towards the rarer; and the* Force *wherewith*

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a Body endeavours to recede, is as the Quantity of Matter in the Body, and the Increaſe of the Denſity of the Æther at the Centre of Gravity of the Body, taken together. When it is put into a vibrating Motion by the Rays of Light, the Will of Animals, or other Cauſes; its Vibrations or Pulſes move ſwifter than Light, and by Conſequence, above 700000 *times ſwifter than Sounds. Its Denſity and expanſive* Force, *are both increaſed in Proportion to the Strength and Vigour of its vibrating Motion; which Motion, like the vibrating Motion of the Air for the Production of Sounds, grows weaker, as the Square of the Diſtance from the Place in which it is excited increaſes. And* laſtly, *its vibrating Motion is regularly propagated thro' Bodies made of uniform denſe Matter, but is reflected, refracted, interrupted or diſordered by any Unevenneſs in the Bodies.*

These

Theſe are the principal Properties, with which this Æther muſt neceſſarily be endued; which I thought fit to mention, before I ſhew the Manner in which it cauſes the Motion of the Muſcles.

When by the Power of the Will a vibrating Motion is excited in the Æther, in thoſe Ends of the Nerves which terminate in the Brain; that Motion is in an Inſtant propagated thro' their ſolid and uniform *Capillamenta* to the Membranes of the Muſcles, and excites a like Motion in the Æther lodged within thoſe Membranes; and a vibrating Motion raiſed in the Æther within the Membranes, increaſes its expanſive Force; an Increaſe of that Force ſwells the Membranes; a Swelling of the Membranes cauſes a Contraction of the fleſhy Fibres; and that Contraction, a Motion in the Parts to which the Extremities of the Muſcles

Muſcles are faſtened. Thus the Limbs and other Parts of Animals are moved by their Muſcles, each of which has its two Ends faſtened to two Bones, whereof one is always more moveable than the other; on which Account, when its fleſhy Fibres are ſhortened by the ſwelling of the Membranes, the more moveable Bone is drawn towards that which is more fixed, by means of an intervening Joint upon which it turns.

As ſoon as the Will ceaſes to act, the vibrating Motion of the Æther cauſed by that Action ceaſes; in like manner as the Pulſes of the Air cauſing Sounds ceaſe, on a Ceſſation of the Tremors of ſonorous Bodies, by which they are excited; and a Ceſſation of the vibrating Motion of the Æther, cauſes a Diminution of its expanſive Force; and a Diminution of that Force, gives an Opportunity to the dilated Membranes to contract, by the attractive Powers of their Parts, and thereby to lengthen the fleſhy Fibres. Another Cauſe of the lengthening of the fleſhy Fibres and Dilatation of a Muſcle, is a vibrating Motion, excited in the Æther lodged in the fleſhy Fibres by their Contraction: For that vibrating Motion will increaſe the expanſive Force of the Æther, and that increaſed Force will lengthen the Fibres, the very Inſtant the Cauſe which contracted them ceaſes to act. Theſe two Forces added together, make the whole Force whereby a contracted Muſcle is dilated: For the Experiments above-mentioned fully prove, that the Soul has no immediate Power over the fleſhy Fibres. Thus the Muſcles of Animals are moved by the Æther, when put into a vibrating

ting Motion by the Power of the Will.

I have ſhewn that Heat, Punctures or Wounds, and Ligatures on the Nerves in the Inſtant they are made, have a Power of contracting the Muſcles: And from the Effects of vomiting and purging Medicines, and ſome Poiſons, we learn, that the ſubtile and active Particles of ſome Bodies have a like Power: But ſince all theſe Things, however different they are in themſelves, do notwithſtanding produce the ſame Effect which the Will does, they muſt do it in the ſame Manner, that is, by exciting a vibrating Motion in the Æther within the Nerves and Membranes of the Muſcles. And therefore the *Propoſition* is true.

Cor. 1. The Motion of the Muſcles becomes weak, either from too weak a vibrating Motion of the Æther in their Membranes and Fibres; or an Unfitneſs in the Membranes and Fibres to be moved with Vigour by a due Degree of that vibrating Motion. The vibrating Motion excited by a given Force becomes weak, when the Æther becomes rare; and the Æther becomes rare, when the Membranes and Fibres become denſe, from Moiſture ſoaking into their Pores, from Compreſſion, or other Cauſes. And the Membranes and Fibres become unfit to be moved with Vigour, when they are rendered ſtiff by Age, too hard Labour, or other Cauſes.

Cor. 2. Muſcles grow larger and ſtronger by moderate Exerciſe: For the expanſive Force of the Æther muſt be increaſed, before it can move the Muſcles; and a frequent Increaſe of this Force in Muſcles much moved, muſt of Neceſſity increaſe

creaſe both their Magnitudes and Strengths. Hence labouring Perſons have larger and ſtronger Muſcles, than Perſons who lead a ſedentary and inactive Life.

Cor. 3. The Blood moving thro' a Muſcle, is preſſed forward by the Force of its Contraction; but after a Muſcle is contracted, if it be kept in that State by the conſtant Action of the Force which contracted it, leſs Blood will flow through it in a given Time than did before: For the Blood-Veſſels interwoven in the Membranes, are compreſſed and contracted by the ſwoln Membranes and ſhortened and hardened Fibres: And this Contraction of the Veſſels, while it is exerting, preſſes the Blood forward; but afterwards hinders the Blood from flowing through the Muſcle in that Quantity it did before. Hence

Ex-

Exerciſe performed by the Motion of the Muſcles, accelerates the Motion of the Blood; and Cramps and other permanent Convulſions retard it.

Cor. 4. The Magnitude of a Muſcle may be but little altered by its Contraction: For if the Contraction of the fleſhy Fibres be nearly equal to the Swelling of the Membranes, its Magnitude will continue much the ſame, though its Figure be changed.

Cor. 5. The Forces of correſponding Muſcles in healthful Bodies, are meaſured by their Weights, and the Strengths of the vibrating Motions of the Æther in them, taken together.

Cor. 6. If a great Increaſe of the vibrating Motion of the Æther in the Nerves and Membranes of one

Part

Part of the Body be, *from ſome Cauſe*, attended with a Diminution of its vibrating Motion in the Nerves and Membranes of other Parts; then it may be in the Power of Art to quiet a Diſturbance in one Part, by raiſing a ſtronger Diſturbance in another: As by Bliſters, Cauteries, and other powerfully ſtimulating Bodies, applied to one Part of a Human Body, we often relieve Pain, and quiet convulſive Motions in other Parts of it. The Exiſtence and Nature of *ſuch a Cauſe* I ſhall conſider more fully in its proper Place, it being beſide my Deſign to enlarge upon it at preſent.

Of

Of the Motion of the Blood.

Proposition IX.

THE *Blood moves in the Arteries and Veins with a kind of Circular Motion.*

Harvey has proved this from Experiments and Observations: For he has shewn, that the Blood flows out of the Trunk of the *Vena cava*, into the right Auricle of the Heart; out of that, into the right Ventricle; thence, thro' the Lungs, into the left Auricle and Ventricle; out of the left Ventricle, into the *Aorta*; whose Branches convey it to all Parts of the Body, except the Lungs, and pour it into the smallest Branches of the Veins; out of of which it paſſes into Branches ſtill larger, till at laſt, by the *Vena cava* it is brought back to the Heart. And this Motion of the Blood from and to the Heart, is called its *Circulation, or Circular Motion.*

The Heart and Arteries act upon the Blood, in generating and keeping up its Motion, in the following Manner. When the Auricles are filled with Blood by the Veins, the right Auricle by the *Vena cava*, and the left by the Pulmonary Vein, they both contract at one and the ſame time, and preſs the Blood which they contain into the Ventricles; and when the Ventricles are filled with Blood, they likewiſe contract at one and the ſame Time, and preſs the Blood which they contain into the Arteries; the right Ventricle into the Pulmonary Artery, and the left into the *Aorta*. The Arteries are dilated by the Blood, forcibly preſſed into them by the Ventricles; and as ſoon as the Ventricles are emptied, and their Contraction is over, the dilated Arteries contract, and preſs the Blood forward into the Veins. And thus the Motion of the Blood is generated and kept up, by the Forces of the Heart and Arteries.

The Blood is kept from regurgitating, by the Valves of the Heart and Veins. The Valves at the Entrance of the Auricles into the Ventricles, open when the Auricles contract, and permit the Blood to flow into the Ventricles; and ſhut when the Ventricles contract, and prevent its Return into the Auricles. The Valves at the Origins of the *Aorta* and Pulmonary Artery, open when the Ventricles contract, and ſuffer the Blood to flow into the Arteries; and ſhut when the Arteries contract, and hinder

der it from flowing back into the Ventricles. And the Valves of the Veins open to let the Blood move forward towards the Heart; and ſhut to prevent its Return into the Arteries.

Cor. 1. The two Ventricles of the Heart throw out equal Quantities of Blood in each Syſtole: For if they threw out unequal Quantities; then, ſince they always contract together, more or leſs Blood would flow into the Lungs, than flows out of them, in a given Time: Which muſt of Neceſſity ſoon put an End to Life.

Cor. 2. As much Blood flows thro' each Ventricle of the Heart, and through the Lungs; as flows through all the reſt of the Body in the ſame Time.

Cor. 3. The Arteries have a Pulſe, and the Veins no Pulſe: For the Arteries have a ſtronger muſcular Coat than the Veins, from their ſuſtaining a greater Preſſure againſt their Sides from the Blood forced into them by each Syſtole of the Heart; and they ſuſtain a greater Preſſure againſt their Sides than the Veins, from a greater Quantity of Blood lying before them, which gives a greater Reſiſtance to the Blood forced into them by the Heart. Now the Sides of both Arteries and Veins being ſoft and dilatable, it is evident, that the whole Syſtem of Veſſels muſt ſwell, when Blood is forcibly preſſed into it by the Heart in its Syſtole; and endeavour to contract again, when the Force of the Heart ceaſes to act in its Diaſtole: But when the Arteries and Veins begin to contract after every Syſtole of the Heart, the Arteries,

ries by the greater Strength of their Muſcular Coat, overpower the Veins; and by preſſing the Blood into them, hinder them from contracting: Therefore the Arteries by dilating and contracting, have a Pulſe; and the Veins for want of this alternate Motion, have no Pulſe.

Propoſition X.

THE *Velocity of the Blood is leſs in the Sum of the Branches of both Arteries and Veins, than in their reſpective Trunks; and it is leſs in the Veins, than in their correſponding Arteries.*

For it has been found by meaſuring the Veſſels, that the Branches of an Artery or Vein taken all together, are wider than the Trunk out of which they ariſe; and that the

the Veins are wider than their corresponding Arteries: And therefore the *Proposition* is true, by the 5*th Corollary* of the 5*th Proposition*.

Cor. 1. Hence it appears, that the Velocity of the Blood is continually lessened in the Arteries from their Trunks to their smallest Branches; and increased continually in the Veins from their smallest Branches to their Trunks: And by Consequence, that the Velocity is least in the last and smallest Branches of the Arteries and Veins.

Cor. 2. Since the Velocity of the Blood is least in the smallest Branches of the Arteries and Veins; it necessarily follows, that the Blood will be more liable to be obstructed by Cold and other Causes, in its Course thro' those Vessels, than thro' any others.

Proposition

Propoſition XI.

THE *Velocity of the Blood in one and the ſame Artery or Vein, is the ſame both in the Syſtole of the Heart, and in its Diaſtole; when the Arteries are dilated, and when they are contracted.*

For ſince the Veins have no Pulſe, the Blood muſt neceſſarily flow thro' them with the ſame Velocity when the Arteries are dilated, and when they are contracted; which it could not do, if it moved faſter through the Arteries when they are dilated, than when they are contracted; in the Syſtole of the Heart, than in its Diaſtole: And therefore the *Propoſition* is true.

Cor. 1. Hence it appears, that while the progreſſive Motion of the Blood

Blood continues the ſame; the Force which generates this Motion, muſt by its conſtant Action continually generate as much Motion as is deſtroyed by the Reſiſtance of the internal Surface of the whole Syſtem of Blood-Veſſels; otherwiſe it would be impoſſible, that the Velocities of the Blood in the ſame Veſſels ſhould be the ſame in the Syſtole of the Heart, and in its Diaſtole; when the Arteries are dilated, and when they are contracted.

This will not appear ſtrange when we conſider, that there are other Motions in Nature which are uniform, notwithſtanding the conſtant Action of a given moving Force. Of this kind is the Motion of a Ship, generated by a Wind blowing conſtantly and uniformly; which Motion is at firſt accelerated, till as much Motion is continually communicated to the Water and Air

Air by the Ship moving along; as is generated in it by the conſtant and uniform Action of the Wind: And after that, it continues uniform, notwithſtanding the conſtant Action of the Wind. Of this kind alſo, is the Motion of a Body deſcending in Water; which Motion is accelerated, till the Motion communicated to the Water by the deſcending Body, becomes equal to the Motion generated in the Body by the conſtant and uniform Action of its Weight in Water; and after that, the Motion continues uniform, notwithſtanding the conſtant Action of this Weight.

Propoſition XII.

THE *Velocities of the Blood in the correſponding Blood-Veſſels of Bodies ſituated alike with re-*

ſpect to the Horizon, are in the ſubduplicate Ratios of the Diameters of the Veſſels, that is, V. v :: √D. √d.

For from Anatomy and the Similarity of the correſponding Parts of human Bodies we learn, that their Syſtems of Blood-Veſſels have the ſame Number of correſponding Veſſels; and that correſponding Veſſels have like Situations and Capacities, in Bodies ſituated alike with reſpect to the Horizon, that is, any two correſponding Veſſels are ſituated alike with reſpect to the reſt of the Veſſels, and their Capacities are as the Capacities of the whole Syſtems.

The Forces of the Hearts are as their Weights, and the Strengths of the vibrating Motions of the Æther in their Nerves and Membranes, taken together, by *Cor.* 5. *Prop.* 8. But the Strengths of the vibrating Motions

Motions of the Æther, ſetting aſide the Power of the Soul and other diſturbing Cauſes, are as the Heats of the Hearts; and the Heats of the Hearts, as the Heats of the Blood; and the Heats of the Blood are much the ſame in all healthful Bodies, as I have found by the Thermometer: And therefore, ſetting aſide the Power of the Soul and other diſturbing Cauſes, the Forces of the Hearts are as their Weights. The Weights of the Hearts of a ſtrong Man and a Child newly born, were as 16 and 1; the Diameters of their *Aortas* as 2 and 1; and the Lengths of their Bodies as 4, and 1: Now ſince the Lengths of correſponding Blood-Veſſels are as the Lengths of the Bodies, and the Diameters of correſponding Veſſels as the Diameters of the *Aortas* in Bodies ſituated alike with reſpect to the Horizon; it is evident from this

Inſtance, that the Weights of the Hearts are as the Capacities of correſponding Veſſels, or as the Capacities of the whole Syſtems, in Bodies ſituated alike with reſpect to the Horizon: And therefore the Forces of the Hearts, when they are not diſturbed by the Power of the Soul or other Cauſes, are as the Capacities of correſponding Blood-Veſſels, or as the Capacities of the whole Syſtems in Bodies ſo ſituated; and the Forces generating the Motions in correſponding Veſſels, are as the Capacities of thoſe Veſſels, and by Conſequence, as the whole Forces of their Hearts. And farther if we conſider, that the Syſtem of Blood-Veſſels ſwells or contracts as the Force of the Heart is increaſed or leſſened by the Soul, Heat or Cold, or other Cauſes; and on the contrary, that the Force of the Heart is increaſed or leſſened, as the

the Syſtem ſwells or contracts by Heat or Cold; no Doubt can be made, but that the Forces of the Hearts are ever proportional to the Capacities of their reſpective Syſtems of Blood-Veſſels; and that the Forces generating the Motions in correſponding Veſſels, are as the whole Forces of their Hearts in Bodies ſituated alike with reſpect to the Horizon.

And theſe Things being true, the *Propoſition* is true, by the *Firſt Corollary* of the *Fourth Propoſition*.

Cor. 1. Hence it appears, that the Velocity of the Blood increaſes continually from the Birth, till Bodies are arrived at their full Lengths; and afterwards, it increaſes or leſſens in the ſame Bodies, as their Syſtems of Blood-Veſſels ſwell or contract, either from an Increaſe or Diminution of the Quantity, or a Diminution or Increaſe of the Denſity of the Blood.

Cor.

Cor. 2. When healthful Bodies are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of diſturbing Cauſes; the Velocities of the Blood in correſponding Blood-Veſſels, are in Ratios compounded of the ſubquadruplicate Ratios of the Quantities of Blood contained in their whole Syſtems of Blood-Veſſels directly, and the ſubquadruplicate Ratios of the Lengths of the Bodies inverſly. For the Heat of the Blood is the ſame in Bodies under theſe Circumſtances, as I have found by the Thermometer, and conſequently its Denſity is given; but the Denſity of the Blood being given, the Capacities of correſponding Blood-Veſſels will be as the Quantities of Blood contained in them, or as the Quantities contained in the whole Syſtems; therefore, putting Q and q for the Quantities contained in two

two whole Syſtems, $D^2 L . d^2 l :: Q . q$; whence $\sqrt{D} . \sqrt{d} :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}} . \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}$: But by this *Propoſition*, $V . v :: \sqrt{D} . \sqrt{d}$; and therefore in Bodies under the Circumſtances mentioned in this *Corollary*, $V . v :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}} . \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}$.

Cor. 4. If two healthful Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon, and their Hearts be free from the Influences of diſturbing Cauſes; the Velocities of the Blood in any two correſponding Blood-Veſſels of the two Bodies, or in any one and the ſame Blood-Veſſel of the ſame Body at two different Times, will be in the ſubquadruplicate Ratios of the whole Quantities of Blood contained

tained in the two Bodies, or in the ſame Body at thoſe different Times, by the laſt *Corollary:* If $L=l$; then will $V.v :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$.

That the Velocities of the Blood as they are expreſſed in this *Corollary*, may be found out more eaſily, I have added the following Table: Which in the two Columns under Q, contains different Quantities of Blood; and in the two Columns under V, different Velocities expreſſed in the biquadrate Roots of thoſe Quantities. For Inſtance, if the Quantities of Blood in two different Bodies of equal Lengths, or in one and the ſame Body at two different Times, be as 20 and 18; the Velocities in the correſponding Blood-Veſſels of the two Bodies, or in the ſame Blood-Veſſel of the ſame Body at different Times, will be as the Numbers 21147 and 20597, if the

the Bodies be under the Circumstances supposed in this *Corollary*.

Q	V	Q	V
1	10000	26	22581
2	11892	27	22745
3	13160	28	23003
4	14142	29	23206
5	14953	30	23403
6	15650	31	23596
7	16265	32	23784
8	16817	33	23968
9	17320	34	24147
10	17790	35	24323
11	18211	36	24495
12	18612	37	24663
13	18988	38	24828
14	19343	39	24990
15	19680	40	25149
16	20000	41	25304
17	20302	42	25457
18	20597	43	25607
19	20878	44	25755
20	21147	45	25900
21	21407	46	26043
22	21657	47	26183
23	21899	48	26321
24	22134	49	26457
25	22361	50	26591

Cor. 4. If the Diameters of correſponding Blood-Veſſels be in the ſubduplicate Ratios of the Lengths of the Bodies; the Velocities in thoſe Veſſels will be in the ſubquadruplicate, and the Capacities of the whole Syſtems in the duplicate Ratios of the Lengths of the Bodies. If $D. d :: \sqrt{L}. \sqrt{l}$; then will $V. v :: L^{\frac{1}{4}}. l^{\frac{1}{4}}$; and $D^2 L. d^2 l :: L^2. l^2$.

From the Inſtance mentioned in the Proof of this *Propoſition* it is evident, that theſe Proportions of the Diameters of correſponding Blood-Veſſels and of the Capacities of the whole Syſtems obtain in ſome Bodies, when ſituated alike with reſpect to the Horizon; and it is as certain, that they do not obtain in all Bodies ſo ſituated; becauſe of Bodies of the ſame Length, ſome, from a different Uſe of the Non-naturals or other Cauſes, have larger

ger Blood-Veſſels than others: Now if theſe Proportions be obſerved in the moſt perfect and beſt proportioned Bodies, they will likewiſe obtain in all Bodies of different Lengths, taking thoſe of each Length one with another, when they are ſituated alike with reſpect to the Horizon, that is, the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths ſo ſituated, each Mean being taken from a conſiderable Number of Diameters of correſponding Blood-Veſſels of Bodies of the ſame Length, will be in the ſubduplicate; and the mean Capacities of the whole Syſtems in the duplicate Ratios of the Lengths of the Bodies: Otherwiſe there could be no Regularity and Uniformity preſerved in the Species.

Lengths in Inches.	Velocities.	Capacities of the Syſtems.
72	2913	5184
66	2850	4356
60	2783	3600
54	2711	2916
48	2632	2304
42	2546	1764
36	2449	1296
30	2340	900
24	2214	576
18	2059	324

This Table contains in the firſt Column, the Lengths of Bodies in Inches; in the ſecond, the true or mean Velocities of the Blood in the correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon; and in the third, the true or mean Capacities of the whole Syſtems of Blood-Veſſels of Bodies of thoſe Lengths. For Inſtance,

ſtance, the true or mean Velocities of the Blood in the correſponding Blood-Veſſels of Bodies alike ſituated whoſe Lengths are 72 and 36, are as the Numbers 2913 and 2449; and the true or mean Capacities of their whole Syſtems of Blood-Veſſels, as the Numbers 5184 and 1296.

Cor. 5. If the Diameters of correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon, be as the n Power of the Lengths of the Bodies; the Velocities in thoſe Veſſels will be as the $\frac{n}{2}$ Power; and the Capacities of the whole Syſtems, and Quantities of Blood if the Forces of the Hearts are not diſturbed, as the $2n+1$ Power of the Lengths of the Bodies, that is, $V . v :: L^{\frac{n}{2}} . l^{\frac{n}{2}}$, and $D^2 L . d^2 l :: L^{2n+1} . l^{2n+1}$, and $Q . q :: L^{2n+1} . l^{2n+1}$ if $D^2 L . d^2 l :: Q . q$.

For

For Example, If the Diameters of correſponding Veſſels be in the ſubtriplicate Ratios of the Lengths of the Bodies, and the Lengths of the Bodies be 72 and 18; the Velocities will be as the Numbers 126 and 100; and the Capacities of the Syſtems and Quantities of Blood, as the Numbers 10 and 1.

Propoſition XIII.

THE *Velocities of the Blood in the correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon, are in Ratios compounded of the ſimple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syſtole directly, and of the duplicate Ratios of the Diameters of the Veſſels and the ſimple Ratios of the Times of one Syſtole inverſly. If* K, k *denote the Mag-*

Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Syſtole, and T, t *the Times of one Syſtole; I ſay, that* V . v :: $\frac{K}{D^2T}$. $\frac{k}{d^2t}$.

For the Velocities of the Blood in any two correſponding Blood-Veſſels, are directly as the Spaces deſcribed by the Blood in the Times of one Syſtole, and inverſly as thoſe Times: But the Spaces deſcribed by the Blood in the Times of one Syſtole, are as the Magnitudes of the Quantities of Blood which flow into thoſe Veſſels in the Times of one Syſtole apply'd to the Orifices or Squares of the Diameters of the Veſſels; and the Magnitudes of thoſe Quantities are as the Magnitudes of the Quantities thrown out of their Hearts in one Syſtole, if the Bodies be ſituated alike with reſpect to to the Horizon: And therefore, the Velocities in the correſponding Blood-Veſſels of Bodies ſo ſituated, are in Ratios compounded of the ſimple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syſtole directly, and of the duplicate Ratios of the Diameters of the Veſſels and the ſimple Ratios of the Times of one Syſtole inverſly: Which was to be proved.

Cor. 1. If the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Syſtole, be as the Capacities of any two correſponding Blood-Veſſels; the Velocities in thoſe Veſſels will be as the Lengths of the Bodies directly, and as the Times of one Syſtole of their Hearts inverſly. If K. k :: $D^2L.\ d^2l$; then will V. v :: $\frac{L}{T} \cdot \frac{l}{t}$.

This

This *Corollary* obtains in Bodies which are ſituated alike with reſpect to the Horizon, and whoſe Hearts are not influenced by diſturbing Cauſes: For the Hearts of Bodies under theſe Circumſtances, will throw out in each Syſtole Quantities of Blood whoſe Magnitudes are equal to the Capacities of their Ventricles; but the Capacities of the Ventricles are as the Magnitudes of the Hearts; and the Magnitudes of the Hearts are as their Weights; (for I have found their Denſities to be ſo nearly equal, that their Differences may be neglected) and the Weights of the Hearts are as their Forces; and their Forces as the Capacities of correſponding Blood-Veſſels by the *Proof* of the 12*th Propoſition*; and therefore $K.k :: D^2 L. d^2 l$.

Cor. 2. The true Times of one Syſtole of the Hearts of regular and well-proportioned Bodies of different Lengths, and the mean Times of one Syſtole of the Hearts of all Bodies of different Lengths, each Mean being taken from a conſiderable Number of Bodies of the ſame Length, are, when the Bodies are ſituated alike with reſpect to the Horizon and their Hearts are free from the Influences of all diſturbing Cauſes, as the biquadrate Roots of the Cubes of the Lengths of the Bodies, that is, $T.\,t :: L^{\frac{3}{4}}.\, l^{\frac{3}{4}}$. For in theſe Caſes, $V.\,v :: L^{\frac{1}{4}}.\, l^{\frac{1}{4}}$ by the *4th Corollary* of the 12*th Propoſition*, and $V.\,v :: \frac{L}{T}\, \frac{l}{t}$ by the preceding *Corollary* of this *Propoſition*; and therefore $L^{\frac{1}{4}}.\, l^{\frac{1}{4}} :: \frac{L}{T}.\, \frac{l}{t}$; whence $T.\, t :: L^{\frac{3}{4}}.\, l^{\frac{3}{4}}$.

Pro-

Propofition XIV.

THE *Velocities of the Blood in the correfponding Blood-Veffels of Bodies fituated alike with refpect to the Horizon, are in Ratios compounded of the fimple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syftole and the fimple Ratios of the Numbers of their Pulfes in a given Time directly, and the duplicate Ratios of the Diameters of the correfponding Veffels inverfly. If* P, p *denote the Numbers of Pulfes in a given Time of two Bodies fituated alike with refpect to the Horizon; then will* $V . v :: \frac{KP}{D^2} . \frac{kp}{d^2}$.

PROOF *by* EXPERIMENTS.

I Took the Pulſes in a Minute, and meaſured the Lengths, of a great Number of Bodies: I took the Pulſes when the Bodies were ſitting, that they all might be ſituated alike with reſpect to the Horizon; and in the Morning before Breakfaſt, that their Hearts might be as free as poſſible from the Influences of all diſturbing Cauſes: And when I had got a very large Stock of Obſervations, I took the Means of the Pulſes, each Mean from a conſiderable Number of Bodies of the ſame Length; and found thoſe Means to be nearly as the biquadrate Roots of the Cubes of the Lengths of the Bodies inverſly, that is, nearly as the mean Times of a Syſtole of their Hearts inverſly, by *Cor.* 2. *Prop.* 12.

And

And ſince the mean Numbers of Pulſes in a Minute of all Bodies, are the true Numbers of Pulſes in a Minute of ſingle Bodies of the ſame Lengths which are regular and well-proportioned, the Numbers of Pulſes in a Minute of regular and well-proportioned Bodies taken ſingly, will likewiſe be as the biquadrate Roots of the Cubes of their Lengths, that is, as the Times of a Syſtole of their Hearts inverſly by the aforeſaid *Corollary*. Now ſince in theſe Inſtances, the Numbers of Pulſes in a Minute are inverſly as the Times of one Syſtole, and there is no Reaſon why this Proportion ſhould not be univerſal; I ſhall therefore conclude, that it is ſo: And that in all Bodies, $P . p :: \frac{1}{T} . \frac{1}{t}$: But by the laſt *Propoſition*, $V . v :: \frac{K}{D^2T} . \frac{k}{d^2t}$: And therefore, $V . v :: \frac{KP}{D^2} . \frac{kp}{d^2}$.

To

Ages in Years.	Lengths in Inches.	Pulses from Observation.	Pulses by the Theory.
	72	65	65
	68	67	68
	60	72	74
14	55	77	79
12	51	82	84
9	46	90	91
6	42	97	97
3	35	113	111
2	32	120	119
1	28	126	132
½	25	137	144
0	18	150	184

To ſhew the near Agreement of the Pulſes from Obſervation with the Pulſes by the Theory, I have added this Table: Which contains in the firſt Column, the mean Ages of growing Bodies when they arrive at the Lengths in Inches ſtanding over

over againſt them in the ſecond Column; in the third Column, the mean Numbers of Pulſes in a Minute in the Morning before Breakfaſt when the Bodies were ſitting; and in the fourth Column, the Numbers of Pulſes in a Minute ſuppoſing them to be inverſly as the biquadrate Roots of the Cubes of the Lengths of the Bodies, and making 65 the firſt Number in the third Column found from Obſervation, the firſt Number in this. In making this Table, I neglected Fractions which were not near an Unit, and put an Unit inſtead of thoſe which were.

It is to be obſerved, that the Number of Pulſes from Obſervation of a Child newly born, falls conſiderably ſhort of the Number of Pulſes by the Theory. The Pulſe of a Child newly born can ſcarcely be perceived. I have often try'd to feel

feel it and count its Numbers, but never ſucceeded: Once I reckon'd 150 Beats or more in a Minute in a Child ſeven or eight Days old. And therefore, though I have made 150 the mean Number, yet I cannot ſay, that it is the true mean Number; but ſuppoſing it to be ſo, its falling ſo much ſhort of the Theory, may in ſome meaſure be accounted for from the Nature of that Cauſe which diſpoſes Infants to ſleep almoſt perpetually; which Cauſe by weakening the vibrating Motion of the Æther in the Nerves and Membranes of the Heart, muſt neceſſarily make the Pulſe ſlower than it otherwiſe would be.

Cor. 1. The Velocities of the Blood in the correſponding Blood-Veſſels of Bodies which are ſituated alike with reſpect to the Horizon, and whoſe Hearts are free from the

the Influences of all diſturbing Cauſes, are in Ratios compounded of the Ratios of the Lengths of the Bodies and the Ratios of the Numbers of their Pulſes in a given Time: For in this Caſe, the Magnitudes of the Quantities of Blood thrown out of the Ventricles of their Hearts in one Syſtole, are as the Capacities of correſponding Blood-Veſſels, that is, $K.\ k :: D^2 L.\ d^2 l$; and therefore, $V.\ v :: LP.\ lp$.

Cor. 2. The Velocities of the Blood in the correſponding Blood-Veſſels of Bodies of equal Lengths, when they are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of all diſturbing Cauſes, will be as the Numbers of their Pulſes in a given Time, by the laſt *Corollary*; by which, when $L = l$, $V.\ v :: P.\ p$. The ſame Proportion will obtain in one and the ſame Body at two different Times, if the Body at thoſe Times be ſituated alike with reſpect to the Horizon, and its Heart be free from the Influences of all diſturbing Cauſes: For the ſame Syſtem having different Magnitudes at different Times, may be conſidered as two Syſtems of equal Lengths.

Cor. 3. The Quantities of Blood, which in a given Time flow thro' the correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon, when their Hearts are free from the Influences of all diſturbing Cauſes, are in Ratios compounded of the Ratios of the Quantities of Blood contained in their Syſtems of Blood-Veſſels and the Numbers of their Pulſes in a given Time. For the Quantities of Blood which flow through correſponding Veſſels in a given Time, are as the Squares of the Diameters of the Veſ-

ſels

ſels and the Velocities of the Blood flowing through them taken together, that is, as D^2V and d^2v: But $V.v :: \frac{KP}{D^2}.\frac{kp}{d^2}$, by this *Propoſition:* And $K.k :: Q.q$, the Denſity of the Blood being given; and therefore, the Quantities of Blood which flow through correſponding Blood-Veſſels in a given Time, will be as $\frac{D^2QP}{D^2}$ and $\frac{d^2qp}{d^2}$, that is, as Qp and qp.

The Quantities of Blood of a tall ſtrong Man and of a Child newly born, are as the Numbers 16 and 1; and the Number of the Man's Pulſes in a Minute in the Morning, when he is ſitting, is 65 by the foregoing Table; and if the Number of the Child's Pulſes in a Minute be 150, as it is there put down; the Quantities of Blood flowing through the Lungs of the Man and of the Child in a given

Time, will be as the Numbers 104 and 15. According to *Tabor*, each Ventricle of the Heart of the Man can contain 1500 Grains of Blood; and consequently, when the Heart is not influenced by disturbing Causes, will throw out 5850000 Grains in an Hour: And each Ventricle of the Heart of the Child will throw out 843750 Grains in the same Time. Therefore, about 835 and 120 *Averdupois* Pounds of Blood will pass through the Lungs of the Man and of the Child in an Hour.

If the Quantities of Blood of strong well-proportioned Bodies be $\frac{1}{12}$ part of their Weights, (as they are according to *Gliſſon* and *Tabor*) and if the Weights of a tall strong well-proportioned Man and a strong well-proportioned Child newly born, be 168 and $10\frac{1}{2}$ *Averdupois* Pounds; the whole Quantities of their Blood will be 14 Pounds and $\frac{7}{8}$ of of a Pound: And consequently, as much Blood as is contained in the Body, will flow $59\frac{1}{2}$ times through the Lungs of the Man, and 137 times through the Lungs of the Child, in an Hour.

Cor. 4. If Bodies be situated alike with respect to the Horizon, and their Hearts be free from the Influences of all disturbing Causes; the Quantities of Blood which flow through their Lungs or other corresponding Parts in a given Time in Proportion to the whole Quantities of Blood contained in their Bodies, will be as the Numbers of their Pulses in a given Time: For the Quantities of Blood which flow through corresponding Blood-Vessels in a given Time, are as QP and qp, by the last *Corollary*; but $\frac{QP}{Q}$ and $\frac{qp}{q}$, are as P and p.

Propofition XV.

IF *Bodies be fituated alike with refpect to the Horizon; the Diameters of correfponding Blood-Veffels will be in the fubquintuplicate Ratios of the Squares of the Products made by the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syftole and the Numbers of their Pulfes in a given Time, that is,* $D. d :: \overline{KP}^{\frac{2}{5}} . \overline{kp}^{\frac{2}{5}}$: *The Velocities in correfponding Veffels will be in the fubquintuplicate Ratios of thofe Products, that is,* $V. v :: \overline{KP}^{\frac{1}{5}} . \overline{kp}^{\frac{1}{5}}$: *And the* Forces *of their Hearts will be in Ratios compounded of the fubquintuplicate Ratios of the Biquadrates of the fame Products and of the fimple Ratios of the Lengths of the Bodies, that is,* $F. f :: \overline{KP}^{\frac{4}{5}} \times L. \overline{kp}^{\frac{4}{5}} \times l.$

For

For the Forces of the Hearts of Bodies ſituated alike with reſpect to the Horizon, are as the Capacities of correſponding Blood-Veſſels, by the Proof of the 12*th Propoſition*, that is, $F. f :: D^2 L. d^2 l$: The ſame Forces are in Ratios compounded of the duplicate Ratios of the Velocities and of the ſimple Ratios of the Diameters and Lengths of the Bodies, by the 4*th Corollary* of the 4*th Propoſition*, that is, $F. f :: V^2 D L. v^2 d l$: But by the 14*th Propoſition*, $V^2. v^2. \frac{\overline{KP}^2}{D^4}. \frac{\overline{kp}^2}{d^4}$; and therefore, $F. f :: \frac{\overline{KP}^2 \times L}{D^3}. \frac{\overline{kp}^2 \times l}{d^3}$: And comparing this Proportion of the Forces with the firſt, we ſhall have $D^2 L. d^2 l :: \frac{\overline{KP}^2 \times L}{D^3}. \frac{\overline{kp}^2 \times l}{d^3}$; whence $D. d :: \overline{KP}^{\frac{2}{5}} . \overline{kp}^{\frac{2}{5}}$.

Ex-

Extracting the Square Root of the laſt Analogy, $\sqrt{D}. \sqrt{d} :: \overline{KP}^{\frac{1}{5}}. \overline{kp}^{\frac{1}{5}}$: But V. v :: $\sqrt{D}. \sqrt{d}$, by the 12*th Propoſition*; and therefore, V. v :: $\overline{KP}^{\frac{1}{5}}. \overline{kp}^{\frac{1}{5}}$.

And ſquaring the ſame Analogy, $D^2. d^2 :: \overline{KP}^{\frac{4}{5}}. \overline{kp}^{\frac{4}{5}}$: But F. f :: $D^2 L. d^2 l$; and therefore, F. f :: $\overline{KP}^{\frac{4}{5}} \times L. \overline{kp}^{\frac{4}{5}} \times l$.

Cor. 1. If two Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon; the Forces of the Hearts of the two Bodies, or of the Heart of the ſame Body at the two Times, will be in Ratios compounded of the ſubquintuplicate Ratios of the Biquadrates of the Products made by the Magnitudes of the Quantities of Blood thrown out in one Syſtole and the Num-

Numbers of Pulſes in a given Time; If L=l; then will F. f :: $\overline{KP}^{\frac{4}{5}}$. $\overline{kp}^{\frac{4}{5}}$.

Cor. 2. If two Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon; and if the Heart of the two Bodies, or the Heart of the ſame Body at thoſe Times, throw out in one Syſtole Quantities of Blood whoſe Magnitudes are equal, that is, if L=l, and K=k: Then, D. d :: $P^{\frac{2}{5}}$. $p^{\frac{2}{5}}$, and V. v :: $P^{\frac{1}{5}}$. $p^{\frac{1}{5}}$, and F. f :: $P^{\frac{4}{5}}$. $p^{\frac{4}{5}}$.

Examples.

Exam. 1. If from ſome Cauſe the Pulſe of the ſame Body become twice as quick as it is in the Morning when the Body is ſitting, and the Heart is free from the Influences of all disturbing Causes; and if it become greater than under the Circumstances now mentioned, from the Heart throwing out its usual Magnitude of Blood in half the Time, that is, if P. p :: 2. 1; and K=k: Then, by the second *Corollary* of this *Proposition*, D and d will be as the Numbers 13195 and 10000, V and v as the Numbers 11487 and 10000, and F and f as the Numbers 17411 and 10000. This seems to be pretty much the Case of a grown Body heated by an *ardent Fever*, or *violent Exercise*, in which the Pulse is greater than ordinarily, and beats about twice as fast as it does in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes; and therefore, in a Body so heated, the Diameters of the Blood-Vessels will be increased in the Proportion of 13195 to 10000, the Velocity of the

the Blood in the Proportion of 11487 to 10000, and the Force of the Heart in the Proportion of 17411 to 10000.

Exam. 2. If the Pulſe of the ſame Body be quicker at one Time than at another, in the Proportion of 80 to 70; and if it be greater from the Heart throwing out its uſual Magnitude of Blood in a leſs Time, that is, if P. p :: 80. 70; and K=k: Then, by the ſecond *Corollary* of this *Propoſition*, D and d will be as the Numbers 10549 and 10000, V and v as the Numbers 10270 and 10000, and F and f as the Numbers 11127 and 10000. The Pulſe is quicker and greater in the *Afternoon*, than it is in the *Morning*; and from many Obſervations, taking one Hour with another of thoſe two Times, it is quicker in grown Bodies one with another, in the Proportion of about 80 to 70: And

	Morning.							Mean	Afternoon.									Mean
Hours	8	9	10	11	12	1	2		3	4	5	6	7	8	9	10	11	
Pulses of A.	65	67	70	73	71	69	70	70	77	77	77	77	76	76	74	74	76	76
Pulses of B.	66	71	72	68	69	67	67	68 1/6	75	81	84	81	79	77	78	78	79	78

therefore, the Diameters of the Blood-Veſſels of the ſame Body will be greater than in the Morning, taking one Hour with another, in the Proportion of 10549 to 10000, the Velocities in the Veſſels will be greater in the Proportion of 10270 to 10000, and the Force of the Heart will be greater in the Proportion of 11127 to 10000.

I have added this Table, to ſhew the Tenour of the Pulſe at different Hours of the Day; it contains the Numbers of Pulſes in a Minute of two healthful Men A and B, when ſitting, at the

the ſeveral Hours from eight a Clock in the Morning to eleven at Night. Theſe Numbers, are Means drawn from a large Number of Obſervations; thoſe of A, from the Obſervations of twelve Weeks; and thoſe of B, from the Obſervations of three Weeks. A eat his Breakfaſt between nine and ten, B his before nine; they both dined together at two, at which Meal B eat more plentifully than A; and they eat little or no Supper.

From this Table it appears, that the Pulſe is ſlower in the Morning, than at any other Time of the Day; that it grows ſomething quicker before Breakfaſt, and a little more ſo after it; that it grows ſlower again before Dinner, and quicker immediately after Dinner; and that the Quickneſs acquired by this Meal, continues for about three or four Hours, and then abates a little; and con-

continues in that State, without any considerable Change, in Bodies which eat and drink little at Night, 'till they go to Rest.

Exam. 3. If from some Cause the Pulse of the same Body becomes quicker than it is in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, in the Proportion of 2 to 1; and if it becomes smaller, from the Heart throwing out in each Systole but a fourth part of the Blood which it throws out in the Morning under the Circumstances now mentioned, that is, if P. p :: 2. 1; and K. k :: 1. 4: Then, by this *Proposition* and its first *Corollary*, D and d will be as the Numbers 7578 and 10000, V and v as the Numbers 8705 and 10000, and F and f as the Numbers 5743 and 10000. If this be nearly the Case of a grown Body in a *malignant Fever*,

Fever, the *Cold Fit of an Ague*, *Convulſions*, and ſome other Diſeaſes; then, when the Body is ſitting, the Diameters of correſponding Blood-Veſſels will be leſſened in the Proportion of 7578 to 10000, the Velocities in the Veſſels will be leſſened in the Proportion of 8705 to 10000, and the Force of the Heart will be leſſened in the Proportion of 5743 to 10000.

Now ſince in the Caſes mentioned in this *Example*, in which the Force of the Heart is leſſened, the Skin is much paler and colder than in a natural and healthful State; and is extremely pale and cold in *dead Bodies*, in which the Force of the Heart is wholly deſtroyed: And on the contrary, ſince in the Caſes mentioned in the *firſt Example*, in which the Force of the Heart is increaſed, the Skin is much redder and warmer than in a natural and health-

healthful State: We may from the Colour and Warmth of the Skin, moſt certainly judge of the Force of the Heart; and at the ſame time ſee, how as that Force gradually leſſens, the Compaſs of the Blood's Motion gradually contracts; till at laſt, that Force wholly ceaſing to act, the Motion wholly ceaſes, even in the largeſt Veſſels neareſt to the Heart.

Propoſition XVI.

IF the Catamenia *flow through* Foramina *in the Sides of the Blood-Veſſels of the* Uterus *into its Cavity, if there be the ſame Number of correſponding* Foramina *in the Sides of correſponding Blood-Veſſels in all healthful Bodies, if this Diſcharge continues a given Number of Days, and during that* Time *of its Continu-*

ance

ance Bodies be ſituated alike with reſpect to the Horizon; the Quantities of one Diſcharge of grown Bodies will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels, that is, putting C, c *for the Quantities of one Diſcharge of two grown Bodies,* $C. c :: D^2\sqrt{D}. d^2\sqrt{d}$.

For the whole Quantities of Blood diſcharged by two healthful Bodies in a given Number of Days, will be as the Quantities diſcharged by any two correſponding *Foramina* in that Time; and the Quantities diſcharged by two correſponding *Foramina*, will be as the Squares of their Diameters and the Velocities wherewith the Blood flows thro' them, taken together: But the Diameters of two correſponding *Foramina* are as the Diameters of two correſponding Blood-Veſſels; and the Velocities wherewith the Blood flows through the *Foramina*, are as the Velocities wherewith the Blood flows through thoſe Veſſels: And therefore, the Quantities diſcharged by two correſponding *Foramina*, will be as the Squares of the Diameters of two correſponding Blood-Veſſels and the Velocities wherewith the Blood flows through them, taken together, that is, as $D^2\sqrt{D}$ and $d^2\sqrt{d}$; for by *Prop.* 12. $V.v :: \sqrt{D}.\sqrt{d}$: And the whole Quantities of one Diſcharge of two healthful Bodies ſituated alike with reſpect to the Horizon, which are as the Quantities diſcharged by two correſponding *Foramina*, will be as $D^2\sqrt{D}$ and $d^2\sqrt{d}$, that is, $C.c :: D^2\sqrt{D}.d^2\sqrt{d}$.

Cor. 1. Since this Diſcharge uſually begins in theſe Countries between the Ages of 14 and 16 Years, at which Ages Bodies are not come

to

to their full Growth; it is evident, if this *Propoſition* be true, that this Diſcharge will continually increaſe from its firſt Appearance till that Time; for both the *Foramina* grow larger, and the Velocity of the Blood increaſes, while Bodies are growing; and it will likewiſe increaſe, from ſome of the *Foramina* being naturally ſmaller than others, on which Account they will neceſſarily, not all at once, but ſucceſſively, become large enough to let the Blood paſs through them.

Cor. 2. If this *Propoſition* be true, this Diſcharge will begin ſooneſt and be greateſt in Bodies which have the largeſt Blood-Veſſels: For it will begin when the *Foramina* are grown large enough to let the red Parts of the Blood (which are its largeſt Parts) paſs thro' them; but they will be ſooneſt large enough to do this, in Bodies which have the largeſt

Blood-Veſſels: And the Quantities of a Diſcharge will be greateſt, becauſe the *Foramina* are largeſt, and the Velocity of the Blood is greateſt, in ſuch Bodies.

Cor. 3. The Quantities of this Diſcharge in grown well-proportioned Bodies of different Lengths, and its mean Quantities in all grown Bodies of different Lengths taking thoſe of each Length one with another, will, if this *Propoſition* be true, be in Ratios compounded of the ſimple and the ſubquadruplicate Ratios of the Lengths of the Bodies; the Diameters of correſponding Blood-Veſſels in theſe Caſes, being in the ſubduplicate Ratios of thoſe Lengths, by *Cor.* 4. *Prop.* 12.

Cor. 4. Hence it appears, that this Diſcharge will be increaſed by all Things which ſwell the Blood-Veſſels; and on the contrary, leſ-
ſened

ſened by all Things which contract them: And therefore, it will be increaſed by whatever increaſes the Power of the Heart, and heats the Blood; and leſſened by whatever leſſens the Power of the Heart, and cools the Blood; for the Blood-Veſſels ſwell or contract, as the Force of the Heart is increaſed or leſſened by Heat or Cold, or other Cauſes.

Cor. 5. Hence it appears, that a Diſcharge muſt continue till the Blood-Veſſels and *Foramina* are ſo far contracted by the Loſs of Blood, that the *Foramina* are too ſmall to let the red Parts of the Blood paſs thro' them; and then it will ceaſe for that Time, and not return again till the loſt Blood be regained, and the Blood-Veſſels and *Foramina* be enlarged to the Dimenſions they were of at the coming on of the preceding Diſcharge; and then another

another Diſcharge will begin, continue the ſame Time, and go off as that did. Thus this Diſcharge happens once a Month, in which Time the loſt Blood is regained; continues in theſe Countries till about the Age of 50; and then wholly ceaſes, from the *Foramina* being too ſmall to let the Blood paſs thro' them. And the *Foramina* become too ſmall from a Rigidity in the Blood-Veſſels, which hinders them from being dilated by the Blood as uſually: For it appears both from Anatomy and common Experience, that the Blood-Veſſels and other ſolid Parts become more rigid, as Bodies advance in Years.

Propoſition XVII.

IF Q *the Quantity of Blood contained in a healthful Body before*

fore a Discharge of the Catamenia *begins, and* P *and* p *the Numbers of Pulses in a Minute a little before and after the Discharge when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, be all known;* C *the Quantity of the Discharge will be known, for it will be equal to* $Q \times \frac{P^4 - p^4}{P^4}$.

For the Heart being supposed to be free from the Influences of all disturbing Causes before the Discharge and after it, the Heat and Density of the Blood will both of them be the same before and after; and therefore, if q denote the Quantity of Blood contained in the Body after the Discharge is over, V. v :: $Q^{\frac{1}{4}}$. $q^{\frac{1}{4}}$, by *Cor.* 3. *Prop.* 12; and V. v :: P. p, by *Cor.* 2. *Prop.* 14; and from these two Analogies, $Q^{\frac{1}{4}}$. $q^{\frac{1}{4}}$ ::

P.

P. p; and Q—q. Q :: P^4—p^4. P^4: But Q—q=C; and conſequently, C.Q :: P^4— p^4.P^4; and $C=\frac{Q\times \overline{P^4-p^4}}{P^4}$.

For *Example*, If the Quantity of Blood contained in the Body at the Beginning of the Diſcharge be 11 *Averdupois* Pounds, and the Pulſes in a Minute before and after the Diſcharge when the Body is ſitting and its Heart is perfectly free from the Influences of all diſturbing Cauſes be 74 and 73; the Quantity of the Diſcharge will be above 9 Ounces: If the Quantity of Blood be 11 Pounds, and the Pulſes in a Minute before and after be 74 and 72; the Quantity of the Diſcharge will be above 18 Ounces.

I have found from Obſervation, that the Pulſe is quicker before the Diſcharge than after it. The Pulſe of a well-proportioned Body 64

Inches

Inches high, in which this Diſcharge was very ſmall, was obſerved at every Hour of the Day for 8 Months together; and the Pulſe of another Body ſix Inches ſhorter, in which this Diſcharge was very great, was obſerved at every Hour of the Day for a Month; and the mean Numbers of Pulſes in a Minute, taken from all the Obſervations made on the two Bodies in the Week before and Week after the Diſcharge, were 74 and 72 in the taller Body, and $79\frac{1}{2}$ and 75 in the ſhorter. The Differences of theſe Numbers before and after the Diſcharge, are too great for the Quantity of the Diſcharge in theſe Climates; which I believe does not ordinarily exceed 12 Ounces in tall and well-proportioned Bodies. And if from more Obſervations of the Pulſe of perfectly healthful Bodies which have this Diſcharge in due Quantities it ſhall be found, that the Differences of its Numbers before and after the Diſcharge make it greater than it really is in theſe Climates; then the Quantity of a Diſcharge cannot be determined by this *Propoſition*, which ſuppoſes the Heart before and after the Diſcharge to be free from the Influences of all diſturbing Cauſes: But it may be determined by the next *Propoſition*, when from Experiments and Obſervations all the Terms uſed in it ſhall be known.

Propoſition XVIII.

IF Q *the Quantity of Blood contained in the Body at the Beginning of a Diſcharge of the* Catamenia, P *and* p *the Numbers of Pulſes in a Minute when the Body is ſitting,* K *and* k *the Magnitudes of the Quantities of Blood thrown out of the Heart*

in

in one Syſtole, and △ *and* δ *the Denſities of the Blood, before and after the Diſcharge, be all known; the Quantity of a Diſcharge will be known,*

$$\textit{for } C = Q \times \frac{\overline{KP}^{\frac{4}{5}} \times \triangle - \overline{kp}^{\frac{4}{5}} \times \delta}{\overline{KP}^{\frac{4}{5}} \times \triangle}.$$

For the Capacities of one and the ſame Blood-Veſſel before and after the Diſcharge, are as the Squares of its Diameters; which Squares when the Body is ſitting are as $\overline{KP}^{\frac{4}{5}}$ and $\overline{kp}^{\frac{4}{5}}$ by the 15*th Propoſition*: And the Quantities of Blood contained in one and the ſame Blood-Veſſel at thoſe Times are as the Squares of its Diameters and the Denſities of the Blood taken together: But the Quantities of Blood contained in the whole Body, are as the Quantities of Blood contained in one and the ſame Blood-Veſſel when the

Body is sitting: And therefore, the Quantities of Blood contained in the whole Body before and after the Discharge, are as $\overline{KP}^{\frac{4}{5}}\times\Delta$ and $\overline{kp}^{\frac{4}{5}}\times\delta$, that is $Q.\,q :: \overline{KP}^{\frac{4}{5}}\times\Delta\,.\,\overline{kp}^{\frac{4}{5}}\times\delta$; whence

$$Q-q=C=Q\times\frac{\overline{KP}^{\frac{4}{5}}\times\Delta-\overline{kp}^{\frac{4}{5}}\times\delta}{\overline{KP}^{\frac{4}{5}}\times\Delta}.$$

Cor. 1. If the Degrees of Heat in the Blood, and consequently its Densities, before and after the Discharge, be equal; and if the Magnitudes of the Quantities thrown out in one Systole before and after be likewise equal, that is, if $\Delta=\delta$, and $K=k$; then will $C=Q\times\frac{P^{\frac{4}{5}}-p^{\frac{4}{5}}}{P^{\frac{4}{5}}}$.

For *Example*, If the Quantity of Blood contained in the Body when the Discharge begins be 11 Pounds, and the Numbers of Pulses in a Minute

nute before and after the Diſcharge when the Body is ſitting be 74 and 70; the Quantity of the Diſcharge will be above $7\frac{1}{2}$ Ounces; and near 9 Ounces, if the Quantity of Blood in the Body when the Diſcharge begins be 12 Pounds. It is to be obſerved, that the Degrees of Heat in the Blood before and after the Diſcharge, may be known by a Thermometer truly adjuſted: And by the Fulneſs of the Pulſe we may judge of the Magnitudes of the Quantities of Blood thrown out in one Syſtole: And therefore, from Experiments and Obſervations carefully made by Perſons who have an Opportunity of doing it, the Quantity of a Diſcharge may be nearly known by this *Propoſition.*

Pro-

Propoſition XIX. Problem II.

THE *Blood-Veſſels of a particular Part of the Body being obſtructed or opened, contracted or dilated; to determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Veſſels of all the other Parts.*

Caſe I. If the Arterial Trunk of a Part be obſtructed or contracted, ſo as either wholly or in ſome Degree to hinder the Blood from flowing through that Part; the Velocity will be increaſed in all the other Parts, and its Increaſe will be greater or leſs, *cæteris paribus*, as the Arterial Trunks of thoſe Parts are nearer to or farther from the Trunk which is obſtructed or contracted, by *Cor. Prop. 7.*

The

The Blood-Veſſels of the Part whoſe Artery is obſtructed or contracted will contract and grow leſs, from a Deſtruction or Diminution of the Force of the Blood's Motion which before the Obſtruction or Contraction of the Trunk kept thoſe Veſſels diſtended: And the Blood-Veſſels of all the other Parts will ſwell and grow larger, by the Force of the augmented Motion of the Blood; and their Swelling and Enlargement will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from the obſtructed or contracted Trunk. Like Changes will be made in the Velocities of the Blood and Magnitudes of the Blood-Veſſels of all the other Parts, if, inſtead of the Arterial Trunk of a Part, any of the Branches of that Part (whether Arteries or Veins) be obſtructed or contracted; becauſe ſuch Obſtruction or Contraction will

leſſen

lessen the Velocity in the Arterial Trunk, by *Cor.* 2. *Prop.* 5; and by Consequence, will produce like Changes in the Velocities and Magnitudes of the Vessels of the other Parts, as would be produced by a real Contraction of that Trunk.

Case II. If the Arterial Trunk of a Part be opened or dilated, the Blood will flow faster into that Trunk and slower through all the other Parts of the Body than it did before; and the Diminution of Velocity in the other Parts will be greater or less, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened or dilated, by *Cor. Prop.* 7.

If the Trunk be opened, and the greatest part of the Blood which flows into it flow out of the Orifice; the Vessels of that Part will contract and grow less, from the

Blood

Blood running out of them, and their not receiving their uſual Supply to keep them diſtended. And the Veſſels of all the other Parts will likewiſe be contracted, from a Diminution of the Velocity of the Blood in them; and their Contraction will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened; and they will undergo like Changes of Magnitude, when the Arterial Trunk is only dilated; tho' the Veſſels of the Part ſupply'd by the dilated Trunk will all ſwell and grow larger, contrary to what happened to them when the Trunk was opened. Like Changes will be made in the Velocities and Magnitudes of the Veſſels of other Parts, when inſtead of the Arterial Trunk, one or more of the Branches (whether Veins or Arteries) of a Part are opened or dilated. For a Dilatation or Opening of any of the Branches will increaſe the Velocity in the Arterial Trunk, by *Cor.* 1. *Prop.* 5; and by Conſequence, will produce like Changes in the Velocities and Magnitudes of the Veſſels of the other Parts as would be produced by a real Dilatation or Opening of the Arterial Trunk.

Caſe 3. If the Venal Trunk of a Part be obſtructed or contracted, the Blood will thereby be either totally or in ſome meaſure hindered from flowing out of the Part; on which Account, its Veſſels will ſwell from the Blood flowing faſter into than it flows out of them for ſome little Time till they can be no farther diſtended: After that, if leſs Blood flow into the Arterial Trunk of the Part than did before; like Changes of Velocity and Magnitude will be produced in the Blood-Veſſels

Veſſels of all the other Parts, as were produced in them by the Obſtruction or Contraction of the Arterial Trunk by the *firſt Caſe*.

Caſe 4. If the Venal Trunk of a Part be opened or dilated, the Blood will flow faſter thro' the Part than it did before; becauſe the Aperture or Dilatation either takes off or leſſens the Reſiſtance ariſing from the Blood which lies before it: The Velocity therefore will be increaſed in the Arterial Trunk, and it will be leſſened in the Veſſels of all the other Parts; and its Diminution in thoſe Veſſels, and the Contraction of their Magnitudes conſequent thereon, will be greater or leſs, *cæteris paribus*, as the Veſſels are nearer to or farther from the Part whoſe Vein is opened or dilated, by the *ſecond Caſe*. The Veſſels of the Part whoſe Venal Trunk is opened will contract, notwithstanding the Velocity of the Blood in them is increased: For by the Aperture, the Resistance given by the Blood lying beyond it to the Motion of the Blood through the Part, will be taken off; and by Consequence, the Velocity of the Blood flowing through the Part will be increased: But this Increase of Velocity beginning in the Vein at the Place of Aperture, and thence successively running thro' the Venal and Arterial Branches, and at last ending in the Arterial Trunk, it is evident, that more Blood will in a given Time flow out of each of these Vessels, than flows in; and by Consequence, all these Vessels will be contracted; and the Contraction will first begin, where the Increase of Velocity first began, and successively go thro' the Vessels in the same Manner as that did.

Cor.

Cor. 1. Hence it appears, that if a Part be overloaded with Blood, it will be ſooneſt emptied by opening the Veſſels of the Part it ſelf; and next, by opening the Veſſels of the Parts which are neareſt to it.

Cor. 2. If the Blood flow too faſt into ſome one Part, from an Aperture or Dilatation of ſome of its Blood-Veſſels; the preternatural Influx of Blood into this Part will be leſſened by increaſing the Motion of the Blood thro' the other Parts.

Cor. 3. If the Blood flow too ſlow into ſome one Part, from an Obſtruction or Contraction of ſome of its Blood-Veſſels; the Motion through this Part will be increaſed by contracting the Veſſels and leſſening the Motion thro' the other Parts.

N. B.

N. B. There may perhaps be ſome little Diſturbances given to theſe Laws of Apertures and Obſtructions, Dilatations and Contractions of the Blood-Veſſels, from ſeveral Inoſculations of Arteries with Arteries, and Veins with Veins; but as theſe Diſturbances cannot be accurately determined, ſo neither can they be conſiderable; as appears from the Succeſs of Practice grounded on theſe Laws.

Propoſition XX. Problem III.

TO *determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Veſſels in different Parts of the Body, when it is ſituated differently with reſpect to the Horizon.*

The

The correſponding Arteries and Veins are every where contiguous; and the Veins are larger than their correſponding Arteries, and conſequently, contain a greater Quantity of Blood: On which Accounts, when the Force of Gravity in a Vein conſpires with or oppoſes the Motion of the Blood through it, that Motion will be more increaſed or leſſened by the Force of Gravity in the Vein, than it is leſſened or increaſed by the ſame Force in the correſponding Artery; and more or leſs Blood will by Virtue of this Force flow through the Vein, than will flow through the Artery in the ſame Time; and therefore, if the Vein and Artery be the two Trunks of a Part; more or leſs Blood will flow out of the Part than flows in, and the Blood-Veſſells of the Part will be contracted or dilated. For Inſtance, in the Day when the Body dy is erect, Gravity conſpires with the Motion of the Blood from the Head, and oppoſes its Motion from the Legs; and in the Night, when the Body is horizontal, Gravity neither conſpires with nor oppoſes the Motion from theſe Parts: And hence the Head will contain leſs, and the Legs more Blood, in the Day than in the Night.

Propoſition XXI. Problem IV.

TO *determine the Influence and Power of the Soul over the Motion of the Heart.*

That the Soul has a very great Power over the Heart appears from the following Inſtances. A dying Man who had had little or no Pulſe, and had been in cold clammy Sweats for ſeveral Hours, was by an an Accident exceedingly alarmed, and thrown into the greateſt Diſturbance of Mind; upon which his Heart and Blood gradually recovered their Motions to a conſiderable Degree, and kept them above an Hour, till his Mind grew calm and eaſy; and then they loſt them again, and he died in leſs than half an Hour. A ſtrong Extenſion of the Legs and Arms by the Power of the Will, has quickened the Pulſe 20 Beats in a Minute, and at the ſame Time made it ſo low, that it could ſcarcely be felt. The Pulſes in a Minute of a Man lying, ſitting, ſtanding, walking at the Rate of two Miles in an Hour, at the Rate of four Miles in an Hour, and running as faſt as he could, were 64, 68, 78, 100, 140, and 150 or more. When a Body ſtands up, the Pulſe begins to grow quicker the very Inſtant the Body begins to riſe, or the Soul begins to exerciſe the Power which raiſes it; and when a Body moves, it grows ſtill quicker; and the Soul exerciſes more Force to move the Body, in Proportion to the Quickneſs of the Motion: When a Body firſt ſtands up and begins to move, the Pulſe is ſmaller than it was before; but grows greater by Degrees, as the Body grows warm by the Motion. A Fit of Laughing has quickened the Pulſe 25 Beats in a Minute: And breathing voluntarily three or four Times faſter than uſually, has quickened it 13 or 14 Beats: The Pulſe is quickened by coughing, ſwallowing, reading loud, or by any Motion that is performed by the Power of the Soul. From hence it appears, that the Motion of the Heart is changed mediately or immediately, by every Change made in the Affections, Activity or Power of the Soul.

Of

Of Respiration.

Proposition XXII.

IF a Wind blow uniformly, and a heated Body be placed in it to cool; the Time of its cooling will be greater or less, as the Quantity of Matter in the Body, or its Degree of Heat at the Time of its being first placed in the Wind, or the Degree of Heat in the Wind, is greater or less; or as the Surface of the Body is less or greater.

For if the Degree of Heat in the Body at the Time of its being first placed in the Wind, and the Degree of Heat in the Wind, be both given; the Time of its cooling will be as the Quantity of Heat in the Body in Proportion to the Measure according to which it is cooled: But the Degree of Heat in the Body being given, its Quantity of Heat will be as its Quantity of Matter; and the Surface of the Body is the Meaſure according to which it is cooled: And therefore, the Time of cooling will be as the Quantity of Matter in the Body in Proportion to its Surface; and by Conſequence, will be greater or leſs, as the Quantity of Matter is greater or leſs, or as the Surface is leſs or greater: If the Body, and Degree of Heat in the Wind, be both given; the Time of its cooling will be greater or leſs, as the Degree of Heat in the Body when firſt placed in the Wind is greater or leſs. From what Sir *Iſaac Newton* has proved in his *Scale of the Degrees of Heat*, it is evident, that the Time of the Body's cooling will not be proportional to its Heat when firſt placed in the Wind:

For

For if one and the ſame Body has different Degrees of Heat, the Times of its cooling will be in Arithmetick Proportion, when the Degrees of Heat are in Geometrick Progreſſion; whence the Time of cooling in Proportion to the Heat, will for the moſt part be greater when the Heat is leſs; and therefore, the Time of cooling will not be proportional to the Degree of Heat in the Body when firſt placed in the Wind: And yet notwithſtanding this, it will ever be greater when the Heat is greater, and leſs when it is leſs; which is all that is affirmed in the *Propoſition*. If the Body, and its Degree of Heat when firſt placed in the Wind, be both given; the Time of cooling will be greater or leſs, as the Wind is warmer or colder, that is, as the Degree of Heat in the Wind is leſs or greater: And therefore, the *Propoſition* is true.

Cor. 1. If a Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly, and the Degree of Heat in the Wind be given; the Time of its cooling, will be as a given Side and the Denſity of the Body taken together, as is evident from the Proof of this *Propoſition.* If the Body be a Cube, the Time of its cooling will be as the Side and Denſity of the Cube; and if a Globe, as the Diameter and Denſity of the Globe; taken together.

Cor. 2. If a homogeneal Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly whoſe Heat is given; the Time of its cooling will be as a given Side of the Body. If the Body be a Cube, the Time of its cooling will be as the Side of the Cube; and if a Globe, as its Diameter.

Pro-

Propoſition XXIII.

IF *a Wind blow uniformly, and a heated Body be placed in it to cool; the Heat which the Body when firſt placed in the Wind will communicate to the Air, and conſequently loſe, in a very ſhort given Time, will be as the Heat and Surface of the Body taken together directly, and the Heat of the Air inverſly. If* S *denote the Surface of the Body,* H *its Degree of Heat when placed in the Wind, and* h *the Heat that is communicated to the Air and loſt in the Body in a very ſhort given Time; I ſay, that* h *will be as* $\frac{SH}{A}$.

For the Wind blowing uniformly, the Air heated by the Body will be always carried off by the Wind, and

and other Air ſucceed into its Place with an uniform Motion; by which Means, equal Parts of Air will be heated by the heated Body in equal Times, and conceive a Heat proportional to the Heat of the Body; and conſequently, one and the ſame heated Body, placed in a Wind blowing uniformly whoſe Degree of Heat is given, will when firſt placed in the Wind communicate to the Air, and conſequently loſe, in a ſhort given Time, a Heat which is proportional to the Heat of the Body: If the Body be different, but its Degree of Heat, and the Degree of Heat in the Wind, be both given; the Body will communicate to the Air, and conſequently loſe, in a very ſhort given Time, a Heat which is proportional to the Surface of the Body: And if both the Body and its Degree of Heat be different, it will communicate to the Air, and conſequently, ly loſe, in a very ſhort given Time, a Heat which is proportional to the Coldneſs of the Wind; which Coldneſs is inverſly as its Degree of Heat: And therefore, the Heat communicated to the Air, and loſt by a Body heated and placed in a Wind blowing uniformly, will be as the Heat and Surface of the Body taken together directly; and the Heat of the Wind inverſly, that is, h will be as $\frac{SH}{A}$.

Cor. 1. If the Heat of the Wind be given; the Heat which is communicated to the Air, and loſt in the Body, in a given Time, will be as the Surface of the Body, and its Degree of Heat when firſt expoſed to the Wind, taken together. If A be given, h will be as SH.

Cor. 2. If the Degree of Heat in the Body, when firſt expoſed to the Wind,

Wind, be given; the Heat communicated to the Air, and loſt in the Body, in a given Time, will be as the Surface of the Body directly; and the Degree of Heat in the Wind inverſly. If H be given, h will be as $\frac{S}{A}$.

Cor. 3. If the Surface of the Body be given; the Heat which is communicated to the Air, and loſt in the Body, in a given Time, will be as the Heat of the Body, when firſt expoſed to the Wind, directly; and as the Heat of the Wind inverſly. If S be given, h will be as $\frac{H}{A}$.

Cor. 4. If the Degree of Heat in one and the ſame Body, when firſt expoſed to the Wind, be given; the Heat which it will communicate to the Air, and conſequently loſe, in a very ſhort given Time, will be inverſly

inverſly as the Heat; or directly as the Coldneſs of the Wind. If S and H be given, h will be as $\frac{1}{A}$.

Propoſition XXIV.

THE *Life of Animals is preſerved by acid Parts of the Air, mixing with the Blood in the Lungs: Which Parts diſſolve or attenuate the Blood, and preſerve its Heat; and by both theſe, keep up the Motion of the Heart.*

I ſhall prove the Truth of this *Propoſition*, from a Series of Experiments and Obſervations.

Firſt then, Animals die, when they are deprived of Air by ſtopping the Wind-Pipe, or putting them in an Air Pump and drawing out the Air. And they likewiſe die ſoon, in a ſmall Quantity of Air ſo cloſely confined, as to have no Communication with the reſt of the Atmoſphere: Small Birds cannot live above three or four Hours in a Quart of ſuch Air; and a Gallon of Air included in a Bladder, and by a Pipe reciprocally inſpired and expired by the Lungs of a Man, will become unfit to preſerve Life, in little more than one Minute of Time.

Hence it appears, that Air is neceſſary to preſerve the Life of Animals: And likewiſe, that a conſtant Supply of freſh Air is neceſſary to that End.

Secondly, A Candle goes out, glowing Coals and red-hot Iron ceaſe to ſhine, and Animals die, in the Air-Pump on drawing out the Air. A Candle goes out, glowing

Coals

Coals and red-hot Iron ceaſe to ſhine, and Animals die, in a ſmall Quantity of Air ſo cloſely confined, as to have no Communication with the reſt of the Atmoſphere. Animals die in Air rendered effete by burning Coals or Candles in it till they are extinguiſhed, and glowing Coals or Candles are extinguiſhed in Air rendered effete by Animals breathing in it till they die. *Hook* found, that if Air rendered effete be blown on live Coals, it produces no other Effect, than to blow off the Aſhes and put out the Fire; and that the more you blow, the more dead is the Light, and the ſooner is the Fire quite extinct; inſomuch that in a very little Time, the Coals become perfectly black without emitting the leaſt Glimpſe of Light or Shining: At which Time, if one Blaſt of freſh Air be blown upon thoſe ſeemingly dead, extinct, and black

black Coals, they all begin to glow, burn, and ſhine afreſh, as if they had not been at all extinct; and the more freſh Air is blown upon them, the more they ſhine, and the ſooner are they burnt out and conſumed: And Animals put into ſuch effete Air ſoon die, tho' for ſome Time they breath, and move their Lungs as before. The Medium found in Damps, is preſent Death to thoſe who breath it; and in an Inſtant, extinguiſhes the brighteſt Flame, the Shining of glowing Coals, or red-hot Iron, when put into it. Common Air, by paſſing thro' red-hot Braſs, red-hot Iron, red-hot Charcoal, or the Flame of Spirit of Wine, becomes unfit to preſerve Life, and the Shining of Fire and Flame.

Hence it appears, that freſh Air preſerves Life in Animals by the very ſame Power, or by the Operation

ration of the very ſame Parts, whereby it preſerves Fire and Flame in ſulphureous and unctuous Subſtances, when once they are kindled.

Thirdly, If two Parts of compound Spirit of Nitre be poured on one Part of Oil of Cloves or Caraway Seeds, or of any ponderous Oil of Vegetable or Animal Subſtances, or Oil of Turpentine thickened with a little Balſam of Sulphur; the Liquors grow ſo very hot in mixing, as preſently to ſend up a burning Flame: If a Drachm of the ſame compound Spirit be poured upon half a Drachm of Oil of Caraway Seeds, even *in vacuo*, the Mixture immediately makes a Flaſh like Gunpowder: And well-rectified Spirit of Wine poured on the ſame compound Spirit flaſhes. Common Sulphur and Nitre powdered, mixed together, and kindled, will continue

tinue to burn under Water, or *in vacuo*, as well as in the open Air.

Now ſince Air is neceſſary to preſerve common Fire and Flame in ſulphureous and unctuous Subſtances, when once they are kindled; and it appears by theſe Experiments, that Fire and Flame may both be produced and preſerved in ſulphureous and unctuous Subſtances, by acid Particles even without Air; it follows, that Air preſerves Fire and Flame by means of acid Particles: And ſince it preſerves the Life of Animals, by the Operation of the very ſame Particles whereby it preſerves Fire and Flame; it likewiſe follows, that it preſerves the Life of Animals by its acid Particles.

Fourthly, The Venal Blood is of a deep purple Colour and the Arterial Blood of a bright red, in all Parts of the Body except the Lungs; and

and in them the Blood is of a dark purple Colour in the Pulmonary Artery, and of a bright red in the Pulmonary Vein. Hence it follows, that the Blood changes its deep purple Colour into a bright red, in the communicant Branches of the Pulmonary Artery and Vein which are ſpread on the Veſicles; and that it changes its bright red into a deep purple Colour, in the communicant Branches of the Arteries and Veins of other Parts. If Blood be drawn out of a Vein, its upper Surface, which is contiguous to the Air, will acquire the ſame bright red Colour which the Blood acquires in the Lungs; and if this red Surface be cut off with a ſharp Knife, the blackiſh Surface of the remaining Blood, being now touched and acted upon by the Air in the ſame Manner as the firſt, will acquire the ſame Colour as that did; and the ſame

Change of Colour will be made in the Bottom of the Cake, if it be turned upwards in the Cup, and expoſed to the Air; and if Blood juſt drawn be ſtirred and agitated, till the Air be intimately mixed with it throughout, its whole Subſtance will ſoon acquire the bright red Colour of Arterial Blood. If the Wind-Pipe be ſtopped with a Cork, and ſome Time after the Operation (when the Air which is ſhut up in the Lungs is made effete, that is, deprived of its acid Parts) Blood be drawn from the Cervical Artery, it will have the ſame dark purple Colour as Venal Blood.

Now ſince from theſe Experiments; the Air muſt touch Venal Blood drawn out of the Body to change its deep purple Colour into a bright red, and the acid Parts of the Air cauſe the ſame Change of Colour in the Blood in the

the Lungs; it will follow, that there muſt be a like Contact of theſe acid Parts with the Blood in the Lungs. And ſince I have ſhewn, that Air preſerves the Life of Animals by its acid Parts; it will likewiſe follow, that the Life of Animals is preſerved by acid Parts of the Air mixing with the Blood in the Lungs.

Fifthly, The bright red Colour acquired by the Blood in the Lungs, from its Purity and Intenſeneſs, is the Red of the ſecond Order of Colours in the Table of Sir *Iſaac Newton's Opticks, p.* 206: But the blackiſh or deep purple Colour of Venal Blood turns into this bright Red, without paſſing through the Colours of Blue, Green, Yellow, and Orange; and therefore, muſt ariſe from the Indigo and Purple of the third Order, and not from the Indigo and Violet of the ſecond: And conſequently by that Table, the tinging Corpuſcles of the Blood are leſſened in the Lungs.

Hence it appears, that the acid Parts of the Air diſſolve or attenuate the Blood in the Lungs.

Oil of Vitriol and Water poured ſucceſſively into the ſame Veſſel, grow very hot in the mixing. *Aqua fortis*, or Spirit of Vitriol, poured upon Filings of Iron, diſſolves the Filings with a great Heat and Ebullition. And the Acid of the Air conſtantly apply'd to ſulphureous and unctuous Subſtances, when once they are kindled, continues to diſſolve them with the Heat of Fire and Flame.

From theſe Experiments we learn, that it is the Nature of Acids to diſſolve Bodies with Heat; and therefore, ſince I have ſhewn that the Acid of the Air diſſolves the Blood; it muſt be allowed, that it warms the

the Blood at the ſame time it diſſolves it.

When Animals are deprived of the Acid of the Air, the Pulſe in leſs than one Minute of Time becomes ſmall and quick; as may be obſerved in a Dog, when his Lungs are made flaccid and without Motion by laying open his Thorax. Upon emptying my Lungs of Air as much as I could, and then ſtopping myBreath; my Pulſe has grown ſmall and quick, with a kind of trembling convulſive Motion, in leſs than half a Minute of Time. And *Thruſton* obſerved the Pulſe to grow ſmaller on an Intermiſſion of Reſpiration, and greater again on repeating it.

Hence it appears, that the Motion of the Heart leſſens immediately on Animals being deprived of the Acid of the Air; and conſequently, that this Acid by diſſolv-

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ing or attenuating the Blood and preſerving its Heat, keeps up the Motion of the Heart.

Therefore the *Propoſition* is true.

But tho' this *Propoſition* be fully proved; yet to obviate Objections, I think it not improper to prove the following Particulars by Experiments and Obſervations.

1. The Motion of the Lungs in breathing is no otherwiſe neceſſary to the Life of Animals, than as by this Motion the Lungs receive a conſtant Supply of freſh Air.

This is proved by the following Experiment. *Hook*, after he had laid open the Thorax of a Dog, cut away his Ribs and Diaphragm, and taken off the Pericardium, kept him alive before the *Royal Society* of *London* above an Hour, by blowing freſh Air into his Lungs with a

pair

pair of Bellows. It was obſerved, that as often as he left off blowing, and ſuffered the Lungs to ſubſide and lie ſtill, the Dog preſently fell into dying convulſive Motions, and ſoon recovered again on renewing the Blaſt. After he had done this ſeveral Times with like Succeſs, he pricked all the outer Coat of the Lungs with the ſlender Point of a ſharp Penknife, and by a conſtant Blaſt made with a double pair of Bellows, he kept the Lungs always diſtended and without Motion; and it was obſerved, that while the Lungs were thus kept diſtended with a conſtant Supply of freſh Air, the Dog lay ſtill, his Eyes were quick, and his Heart beat regularly; but that upon leaving off blowing, and ſuffering the Lungs to ſubſide and lie ſtill, the Dog preſently fell into dying convulſive Motions, and as ſoon recovered again on renewing the Blaſt,

Blaſt, and ſupplying the Lungs with freſh Air.

2. The Motion of the Lungs in breathing does not change the Colour of the Blood in that Part.

This is proved by the following Experiment. *Lower* opened the Pulmonary Vein of a Dog near the left Auricle of the Heart, when his Lungs were kept diſtended and without Motion by a conſtant Supply of freſh Air; and obſerved the Blood drawn to have the ſame florid Colour, as the Arterial Blood of other Parts.

Farther, If the Motion of the Lungs change the Colour of the Blood from a dark Purple to a bright Red; I ſee no Reaſon, why the Motion of the Muſcles when continued for ſome Time ſhould not keep up that red Colour in the Veins; and conſequently, why under ſtrong Exerciſe Venal Blood (contrary to Expe-

Experience) ſhould not be of a bright red Colour. For a ſtrong and vigorous Motion of the Muſcles muſt undoubtedly contribute as much to preſerve the bright red Colour of Arterial Blood, as the Motion of the Lungs contributes to produce it.

3. The Death of Animals and Extinction of Flame in a confined Air, are not cauſed by a Diminution of its Elaſticity.

For there is ſometimes as great a Diminution of Elaſticity in the Air in violent Storms of Wind and Hurricanes, as there is in a ſmall Quantity of confined Air at the Time when Animals die and Candles go out in it; and yet no ſuch Effects follow. Farther, If Animals die and Candles go out in a confined Air, from a Diminution of its Elaſticity; then theſe Effects would not be produced in different Quantities of confined Air, until its Elaſticity was equally diminiſhed in them: But it has been found by Experiments, that at the Time when Animals die and Candles go out in two different Quantities of confined Air, there is a greater Diminution of Elaſticity in the ſmaller Quantity than in the greater: And therefore, Life and Flame are not deſtroyed by a Diminution of the Elaſticity of the Air. This is farther confirmed from an Experiment mentioned above; For if effete Air, however forcibly blown on live Coals, extinguiſhes them in like Manner as it does when in a State of Reſt; then the ſame effete Air, which in a quieſcent State cannot preſerve Life, will not be able to do it when it is preſſed into the Lungs with any Force, even a greater than is ſufficient to ſwell the Air-Veſſels to their uſual Magnitudes: And therefore Animals do not die

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in a confined Air, from the *Veſiculæ* not being ſufficiently dilated on account of a Diminution of the Elaſticity of the Air. A Diminution of the Elaſticity of the Air is no otherwiſe hurtful, than as it hinders the Veſicles from being ſufficiently dilated, and thereby hinders the Blood from receiving its uſual Quantity of Acid in a given Time: Whence the Blood will not be ſufficiently diſſolved and warmed in the Lungs; which will make Reſpiration quick and uneaſy, but cannot cauſe ſudden Death.

Propoſition XXV.

IF healthful Bodies be cloathed alike, and placed in a Wind blowing uniformly, or move gently along in a calm and ſtill Air with the ſame uniform Motion; and if Heat be generated

nerated in their Blood by the Acid of the Air, as faſt as it is loſt by being communicated to the Air in their Lungs and at their Skins: The Heats generated in their Blood in a ſhort given Time, will be as the Sums of the internal Surfaces of their Syſtems of Air-Veſſels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together directly; and as the Degrees of Heat in the Wind or calm Air inverſly. If S, s *denote the Sums of the ſaid Surfaces of two healthful Bodies;* H, h *the Degrees of Heat in their Blood when they are firſt plac'd in the Wind, or begin to move in a calm and ſtill Air;* A, a *the Degrees of Heat in the Wind or Air; and* G, g *the Heats generated in their Blood by the Acid of the Air in a ſhort given Time: I ſay, that* $G . g :: \frac{SH}{A} . \frac{sh}{a}$.

For

For ſince the Bodies are ſuppoſed to be cloathed alike, the external Surfaces of their Bodies will be alike expoſed to the Air; and the internal Surfaces of their Syſtems of Air-Veſſels are always alike expoſed to it, on account of Reſpiration; and ſince it is the ſame thing to move gently along in a calm and ſtill Air with an uniform Motion, as to ſtand ſtill in a Wind blowing with the ſame uniform Motion: It is evident by the 23*d Propoſition*, that the Heats communicated to the Air and loſt in the Blood of healthful Bodies in a very ſhort given Time, will be as the Sums of the internal Surfaces of their Syſtems of Air-Veſſels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together directly; and the Degrees of Heat in the Wind or Air inverſly: But by Suppoſition, the Heat is generated by the

the Acid of the Air as faſt as it is loſt by being communicated to the Air in the Lungs and at the Skin: And therefore, the Heats generated by the Acid of the Air in the Blood of healthful Bodies in a ſhort given Time, will be as the Sums of the internal Surfaces of their Syſtems of Air-Veſſels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together, directly; and the Degrees of Heat in the Wind or Air, inverſly; that is, $G. g :: \frac{SH}{A} . \frac{sh}{a}$.

Cor. 1. If the Degrees of Heat in the Blood of Bodies under the Circumſtances ſuppoſed in this *Propoſition*, and the Degrees of Heat in the Wind or calm Air be reſpectively equal; the Heats generated in the Blood by the Acid of the Air in a given Time, will be as the Sums of of the internal Surfaces of the Syſtems of Air-Veſſels and external Surfaces of the Bodies. If H=h, and A=a; then will G. g :: S. s.

From ſome Experiments made with a Thermometer at the ſame Time and in the ſame Place, I have found the Heats of the warmeſt Parts of the Skin, and conſequently the Heats of the Blood, to be nearly equal in healthful Bodies of all Ages, notwithſtanding the Limbs of old Bodies are conſiderably colder than the Limbs of young Bodies, or Bodies of a middle Age: And if by a larger Experience, this ſhall be found to be univerſally true; then will this *Corollary* obtain in all healthful Bodies in the ſame Place and at the ſame Time: And as theſe Experiments were made when the Bodies were at Reſt, and the Air ſtill and calm, ſo this *Corollary* will likewiſe obtain

obtain nearly in Bodies at Reſt in a calm and ſtill Air, in the ſame Place and at the ſame Time: And granting this, and ſuppoſing the external Surfaces of the Bodies to be proportional to the whole internal Surfaces of their Syſtems of Air-Veſſels, and thoſe whole Surfaces to be proportional to the internal Surfaces of all their Veſicles thro' which the Acid of the Air paſſes into their Blood; then will the Heats generated in a ſhort given Time in the Blood of healthful Bodies, in the ſame Place and at the ſame Time, be as the internal Surfaces of all the Veſicles of their reſpective Syſtems of Air-Veſſels: And if the Veſicles attract the acid Parts of the Air, in Proportion to the Magnitudes of their internal Surfaces, (as I have ſhewn the Blood-Veſſels to act on the Blood by attractive or ſome other Powers, in Proportion to the

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Magnitudes of their internal Surfaces) then will the Heats generated in the Blood by the Acid of the Air in a ſhort given Time, be as the attractive Powers of all the Veſicles.

Cor. 2. If the Degrees of Heat in the Blood of Bodies under the Circumſtances ſuppoſed in this *Propoſition* be equal; the Heats generated in it by the Acid of the Air in a ſhort given Time, will be as the Sums of the internal Surfaces of the Syſtems of Air-Veſſels and external Surfaces of the Bodies, directly; and the Degrees of Heat in the Wind or calm Air, inverſly: If H=h, then will G. g :: $\frac{S}{A} \cdot \frac{s}{a}$.

If by the *Thermometer* it ſhall be found, that the Degree of Heat in the Blood of healthful Bodies is much the ſame at all Seaſons of the

 Year,

Year, and in all Climates; then by this *Corollary*, more or leſs Heat will be generated in the Blood of the ſame Body in a given Time, as the Air is colder or hotter; which cannot be, unleſs the Air when it is cold abounds more with this Acid, than when it is hot: And that it does ſo, appears from Fire burning beſt when the Air is coldeſt, and worſt when it is hotteſt. Now if the Air be cooled by the ſame Acid which generates Heat in the Blood when mixed with it; then as the Air abounds more or leſs with this Acid, the Air will be colder or hotter; and more or leſs Heat will be both generated and loſt in the Blood, in a given Time.

By the 24*th Propoſition*, the Acid of the Air diſſolves or attenuates the Blood, at the ſame Time it generates Heat in it; and the Diſſolution or Attenuation will be greater or leſs, as more or leſs of this Acid is mixed with the Blood in a given Time: And therefore the Blood will be more diſſolved or attenuated in Winter than in Summer, in cold Countries than in hot. And if the Want of a ſufficient Diſſolution or Attenuation of the Blood be the Cauſe of *Malignant Diſeaſes*; Bodies will be more ſubject to ſuch Diſeaſes in Summer and hot Countries, than in Winter and cold Countries.

This is the general Law of the Attenuation of the Blood, and Heat generated in it, in a given Time, on Suppoſition that the Degree of Heat in the Blood is given: However, it may ſometimes happen, that the Attenuation of the Blood and Heat generated in it may not be proportional to the Degree of Coldneſs in the Air. For the Air may be ſo exceſſively cold, and ſo greatly ſaturated with this Acid, that the mutual Attraction of its Particles, ariſing from their Cloſeneſs to one another, may hinder them from being drawn into the Blood in as great a Quantity, as when the Air abounds leſs with them: And whenever this happens, the Fluidity and Heat of the Blood will be deſtroyed faſter than they are generated; and if this continues for any Time, it muſt of Neceſſity put an End to Life. The Caſe here is much the ſame as in Oil of Vitriol, and ſome other Acids; which from their too great Strength will not diſſolve Metals ſo quickly, nor raiſe ſo great a Heat, as the ſame Acids when made weaker.

Propoſition XXVI.

IF healthful Bodies be ſituated alike with reſpect to the Horizon, if the

the Motions of their Hearts and Lungs be free from the Influences of all diſturbing Cauſes, if the mean Capacities of their Syſtems of Air-Veſſels be proportional to the mean Capacities of their Syſtems of Blood-Veſſels, and if the mean Numbers of their Inſpirations in a given Time be proportional to the mean Numbers of their Pulſes in that Time; the mean Quantities of freſh Air inſpired, will be as the mean Quantities of Blood which flow thro' their Lungs in the given Time.

Since by Suppoſition, the Bodies are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of all diſturbing Cauſes; the mean Capacities of the Syſtems of Blood-Veſſels of Bodies of different Lengths, will be as the mean Capacities of correſponding Veſſels, that is, as the Squares of their mean Diameters into their Lengths,

Lengths, or into the Lengths of the Bodies; therefore, the mean Capacities of the Syſtems of Blood-Veſſels of Bodies of two different Lengths, will be as D^2L and d^2l, D and d denoting the mean Diameters of any two correſponding Veſſels, and L and l the Lengths of the Bodies: Since likewiſe by Suppoſition, the mean Capacities of the Syſtems of Air-Veſſels are as the mean Capacities of the Syſtems of Blood-Veſſels; the mean Capacities of the Syſtems of Air-Veſſels of Bodies of two different Lengths, will be as D^2L and d^2l, when the Bodies are ſitting and their Hearts free from the Influences of all diſturbing Cauſes: And ſince alſo by Suppoſition, the mean Numbers of Inſpirations are as the mean Numbers of Pulſes in a given Time; the mean Quantities of freſh Air inſpired by healthful Bodies of two different Lengths,

will

will be as the mean Capacities of their Syſtems of Air-Veſſels and mean Numbers of their Pulſes in that Time taken together, that is, as D^2LP and d^2lp, P and p denoting the mean Numbers of Pulſes in the given Time: But by the *firſt Corollary* of the 14*th Propoſition*, $P.p :: \frac{V}{L} . \frac{v}{l}$: And therefore, the Quantities of freſh Air inſpired in a given Time will be as D^2V and d^2v, that is, as the mean Quantities of Blood which flow thro' the Lungs in the given Time.

The mean Numbers of Pulſes and Inſpirations in a Minute of healthful Bodies of three different Lengths, in the Morning when they were ſitting, were 65, 72, 116, and 17, 19, 30. Hence it appears, that the mean Numbers of Pulſes and Inſpirations in a given Time, are proportional to one another in health-

healthful Bodies, when they are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of all diſturbing Cauſes: And if from Experiments it ſhall be found, that the mean Capacities of the Syſtems of Air-Veſſels are proportional to the mean Capacities of the Syſtems of Blood-Veſſels; then will this *Propoſition* be true in healthful Bodies.

Cor. 1. If this *Propoſition* be true; the mean Quantities of freſh Air inſpired in a given Time by healthful Bodies, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the mean Diameters of correſponding Blood-Veſſels, that is, as $D^2\surd D$ and $d^2\surd d$. For $V. v :: \surd D. \surd d$, by the *Twelfth Propoſition*: But the Quantities of freſh Air inſpired in a given Time, are as D^2V and d^2v, by this *Propo-ſition*:

ſition: And therefore, the Quantities of freſh Air inſpired in a given Time will be as $D^2\sqrt{D}$ and $d^2\sqrt{d}$.

Cor. 2. If this *Propoſition* be true; the mean Quantities of Air inſpired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies, that is, $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$. For $D. d :: L^{\frac{1}{2}}. l^{\frac{1}{2}}$, by *Cor*. 4. *Prop*. 12; and by Conſequence, $D^2\sqrt{D}. d^2\sqrt{d} :: L \times L^{\frac{1}{4}}. l \times l^{\frac{1}{4}}$: But the mean Quantities are as $D^2\sqrt{D}$ and $d^2\sqrt{d}$, by the laſt *Corollary*: And therefore, they will be as $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$.

Cor. 3. If this *Propoſition* be true; the mean Quantities of Air inſpired in a given Time by healthful Bodies of different Lengths, will be in

Ratios compounded of the duplicate Ratios of the Lengths of the Bodies and the simple Ratios of the Numbers of their Pulses in a given Time, that is, as L^2P and l^2p. For by this *Proposition*, the mean Quantities of Air inspired in a given Time are as D^2V and d^2v: But by *Cor.* 4. *Prop.* 12, $D^2 . d^2 :: L . l$, and by *Cor.* 1. *Prop.* 14, $V . v :: LP . lp$: And therefore, the mean Quantities of Air inspired in a given Time will be as L^2P and l^2p.

Cor. 4. If this *Proposition* be true; the Quantities of fresh Air inspired in a given Time in Proportion to the whole Quantities of Blood, will be as the Numbers of Pulses in a given Time. For $\frac{V}{L} . \frac{v}{l} :: P . p$, by *Cor.* 1. *Prop.* 14: But $\frac{V}{L} . \frac{v}{l} :: \frac{D^2V}{D^2L} . \frac{d^2v}{d^2l}$. And therefore, $\frac{D^2V}{D^2L} . \frac{d^2v}{d^2l} :: P . p$.

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SECTION III.

Of Digestion and Nutrition, Secretion, and the Discharges of Human Bodies.

Of Digestion and Nutrition.

Proposition XXVII.

THE *Nourishment of Animals changes its Texture in their Bodies, till it becomes like their solid and durable Parts.*

For the solid and durable Parts of Animal Bodies grow out of their Nourishment: But their Growth is from an Addition and Adhesion of like Parts: And therefore, the Nourishment of Animals changes its

Texture in their Bodies till it becomes like their ſolid and durable Parts.

Cor. 1. Hence it appears, that Animals will not be rightly nouriſhed, when their Nouriſhment does not change its Texture in their Bodies till it becomes like their ſolid and durable Parts.

Cor. 2. Hence it appears, that the Nouriſhment, by changing its Texture in the Bodies of Animals, becomes more dry and earthy than it was before; otherwiſe, it would not be like their ſolid and durable Parts.

Propoſition XXVIII.

THE *Texture of the Nouriſhment is changed in the Bodies of Animals, by a gentle Heat and Motion.*

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The firſt remarkable Change in the Texture of the Nouriſhment is made in the Stomach: In this Bowel the ſolid Parts of the Food are diſſolved and intimately mixed with the Fluids. This Mixture is uſually called *Chyle*.

Some, from obſerving that Fluids have a Power of diſſolving Bodies, have thought that a Fluid in the Stomach diſſolves the Food and turns it into Chyle: But as it does not appear from Experiments and Obſervations, that there is a Fluid in the Stomach endued with ſuch a Power; this Opinion is without Foundation.

Others, from obſerving the great Strength of the Gizzards of Fowls, and that there is commonly Gravel found in them, have imagined, that the Food is diſſolved in the Stomachs of Fowls, and conſequently in the Stomachs of all Animals, by Attri-

Attrition or Grinding. But if this Opinion be examined, it will likewiſe appear to be without Foundation. For the Food of Fowls is moſtly Grain, all Sorts of which are hard and covered with tough Skins; and therefore, before this Food can be diſſolved and turned into Chyle, it muſt be ſoftened, and its Skins ground off; the firſt of which is done by Warmth and Moiſture in the Craw, and the ſecond by Attrition in the Gizzard. By theſe Contrivances, the Food of Fowl is prepared and fitted for Digeſtion; as human Food is by Cookery and other Ways of preparing it, and by the grinding of the Teeth. But if we ſhould grant, that the Food of Fowl is diſſolved and turned into Chyle by Attrition; it will by no means follow, that Food is ſo diſſolved and turned into Chyle in a human Stomach, which has no Gra-

vel

vel in it, and has but very little Muſcular Strength in Compariſon of the Gizzards of Fowls. There may be many different Contrivances in different Species of Animals, to ſoften, groſly divide, and prepare their Food for Digeſtion; but it will not from thence follow, that their Food is digeſted or turned into Chyle by different Cauſes.

The Food is diſſolved and turned into Chyle by a gentle Heat and Motion. Heat makes many Bodies fluid, which are not fluid in Cold. Lead is melted by a Heat eight times as great as the external Heat of a human Body; Tin, by a Heat ſix times as great; Wax, by a Heat twice as great; and Bones, with the Addition of a little Water, are diſſolved in a Digeſter by Heat in a little Time. If the Heat of the Stomach be nearly equal to that of the Blood; this Heat, tho' gentle, may be ſufficient, when

when the Orifices of the Stomach are pretty exactly cloſed, to diſſolve the Food in a few Hours, and turn it into Chyle; eſpecially, when it is aſſiſted by the Motion of the Stomach, which by agitating and mixing the Food will contribute to this End. For ſince Heat can diſſolve ſolid Bodies, and nothing is found in a human Stomach, beſides a gentle Heat and Motion, which can diſſolve the Food and turn it into Chyle; it will follow, that the Food is digeſted or diſſolved, and turned into Chyle, by a gentle Heat and Motion.

The Chyle in moving through the Inteſtines is farther diſſolved by Heat and Motion: And the fineſt Part of this Fluid being conveyed into the Blood, is ſtill farther changed by the ſame Cauſes, namely a gentle Heat and Motion, till it puts on the Form of Blood, and,

and, at laſt, becomes fit to nouriſh the Body, by being made like its ſolid and durable Parts. The Growth of the Pullet in the Shell out of the White of the Egg, is a ſtrong Proof of the Truth of this: For here is manifeſtly nothing, beſides a gentle Heat and Motion, to change the White of the Egg, ſo as to convert it into Blood, and render it fit Nouriſhment for all the Parts of an Animal Body.

Cor. Hence Animals will not be rightly nouriſhed, when the Texture of their Food is not rightly changed in their Bodies by Heat and Motion; which may be owing, either to an Unfitneſs in the Food for ſuch a Change, or to Degrees of Heat and Motion unfit to effect it.

Propoſition XXIX.

THE *conſtituent ſolid Parts of Animals, according to their ſeveral Natures, are endued with peculiar attractive Powers of certain Magnitudes; by which they draw out of the Fluids moving thro' them like Parts in certain Quantities, and thereby preſerve their Forms and juſt Magnitudes.*

For without attractive Powers agreeable to their Natures, the conſtituent ſolid Parts of Animals cannot draw like Particles out of the Fluids moving through them; and conſequently, cannot preſerve their Forms: And unleſs theſe Powers be of certain Magnitudes, they cannot draw thoſe Parts in ſuch Quantities as are proper to preſerve their Magnitudes:

nitudes: And therefore, the *Propo-ſition* is true.

Cor. 1. Hence Bodies will not be rightly nouriſhed by proper Food changed by juſt Degrees of Heat and Motion, when the attractive Powers of their ſolid Parts are changed, either in their Natures, or in their Magnitudes.

Cor. 2. Hence Animals of the ſame Species will grow faſter or ſlower, out of the ſame Nouriſhment rightly changed by Heat and Moon; as the attractive Powers of their ſolid Parts are ſtronger or weaker. And univerſally, their Growth in a given Time will be greater or leſs; as the attractive Powers of correſponding Parts are greater or leſs; or as the Fluids moving thro' thoſe Parts abound more or leſs with ſimilar Particles, that is, with Particles rightly fitted to be attracted by thoſe Powers.

General Scholium.

I have ſhewn that the Nouriſhment of Animals becomes more dry and earthy in their Bodies, and that this Change is effected by a gentle Heat and Motion. How a gentle Heat and Motion cauſe this Change in the Nouriſhment, may be underſtood from what Sir *Iſaac Newton* has delivered concerning the Nature of Salt. This great Man, finding from Experiments and Obſervations, that Salts are dry Earth and watry Acid united by Attraction, and that the Earth will not become a Salt without ſo much Acid as makes it diſſolvable in Water, has given the following Account of the Formation of Particles of Salt.

" As Gravity makes the Sea flow
" round the denſer and weightier
" Parts

"Parts of the Globe of the Earth, "so the Attraction may make the "watry Acid flow round the den- "ser and compacter Particles of "Earth for composing the Parti- "cles of Salt. For otherwise the "Acid would not do the Office of "a Medium between the Earth and "common Water, for making Salts "dissolvable in Water; nor would "*Salt of Tartar* readily draw off "the Acid from dissolved Metals, "nor Metals the Acid from *Mer-* "*cury*. Now as in the great Globe "of the Earth and Sea, the densest "Bodies by their Gravity sink down "in Water, and always endeavour "to go towards the Centre of the "Globe; so in Particles of Salt, "the densest Matter may always "endeavour to approach the Cen- "ter of the Particle: So that a Par- "ticle of Salt may be compared to "a Chaos; being dense, hard, dry,

"and

"and earthy in the Center; and "rare, ſoft, moiſt, and watry "in the Circumference. And "hence it ſeems to be that Salts "are of a laſting Nature, being "ſcarce deſtroy'd, unleſs by draw-"ing away their watry Parts by "Violence, or by letting them ſoak "into the Pores of the Central "Earth by a gentle Heat in Pu-"trefaction, until the Earth be diſ-"ſolved by the Water, and ſepara-"ted into ſmaller Particles, which "by reaſon of their Smallneſs make "the rotten Compound appear of "a black Colour. Hence alſo it "may be that the Parts of Ani-"mals and Vegetables preſerve "their ſeveral Forms, and aſſimi-"milate their Nouriſhment; the "ſoft and moiſt Nouriſhment ea-"ſily changing its Texture by a "gentle Heat and Motion, till it "becomes like the denſe, hard,

"dry,

" dry, and durable Earth in the
" Center of each Particle. But
" when the Nouriſhment grows un-
" fit to be aſſimilated, or the Cen-
" tral Earth grows too feeble to aſſi-
" milate it, the Motion ends in Con-
" fuſion, Putrefaction and Death.
Newt. Opt. p. 361, 362.

Hence it appears, that to render the ſaline Part of the Aliment fit to nouriſh the ſolid Parts of Animals and Vegetables, part of the ſuperficial watry Acid muſt by Heat and Motion be drawn off from the Particles of Salt; by which they will become more denſe, hard, dry and earthy, like the ſolid and durable Parts of the Bodies. And, according to the different Degrees of Heat and Motion in the different Species of Animals and Vegetables, the watry Moiſture will be drawn off in different Proportions, ſo as in each Species to render the Particles like the

the ſolid Parts of the Bodies of that Species.

And farther, if we conſider that Water is a very fluid taſtleſs Salt, and that Animals and Vegetables, with their ſeveral Parts, grow out of Water and watry Tinctures and Salts; we may from what has been ſaid underſtand the Manner in which the Nouriſhment of Animals and Vegetables is changed by a gentle Heat and Motion, till it becomes like the ſolid and durable Parts of their reſpective Bodies.

Of Secretion.

Propoſition XXX.

THE *Glands in the Bodies of Animals, according to their ſeveral Natures and Diſpoſitions, are endued with peculiar attractive Powers by which they ſuck in various Juices from the Blood.*

That the Glands of Animals have ſuch attractive Powers, I ſhall prove from Experiments and Obſervations.

" If two plane poliſhed Plates of
" Glaſs (ſuppoſe two Pieces of a
" poliſhed Looking-Glaſs) be laid
" together, ſo that their Sides be
" parallel and at a very ſmall Di-
" ſtance from one another, and
" then their lower Edges be dip-

 " ped

" ped into Water, the Water will
" riſe up between them. And the
" leſs the Diſtance of the Glaſſes is,
" the greater will be the Height to
" which the Water will riſe. If
" the Diſtance be about the hund-
" redth part of an Inch, the Water
" will riſe to the Height of about
" an Inch; and if the Diſtance be
" greater or leſs in any Proporti-
" on, the Height will be recipro-
" cally proportional to the Diſt-
" ance very nearly. The Weight
" of the Water drawn up being the
" ſame, whether the Diſtance be-
" tween the Glaſſes be greater or
" leſs; the Force which raiſes the
" Water and ſuſpends it muſt be
" likewiſe the ſame, and ſuffer no
" Change by changing the Diſ-
" tance of the Glaſſes. And in
" like Manner, Water aſcends
" between two Marbles poliſhed
" plane, when their poliſhed Sides

" are

" are parallel and at a very little " Diſtance from one another. And " if ſlender Pipes of Glaſs be dip- " ped at one End into ſtagnating " Water, the Water will riſe up " within the Pipe, and the Height " to which it riſes will be recipro- " cally proportional to the Dia- " meter of the Cavity of the Pipe, " and will equal the Height to " which it riſes between two Planes " of Glaſs, if the Semidiameter of " the Cavity of the Pipe be equal " to the Diſtance between the " Planes, or thereabouts. And " theſe Experiments ſucceed after " the ſame Manner *in vacuo* as in " the open Air, (as hath been try'd " before the *Royal Society*,) and " therefore are not influenced by " the Weight or Preſſure of the At- " moſphere. See *Newt. Opt. p.* 366, 367.

Now ſince the Riſe and Suſpenſion of Water between two Glaſs Planes and in ſmall Glaſs Pipes, are not owing to the Preſſure of the Atmoſphere; they muſt be cauſed by an attractive Power in the Glaſs, which will be proportional to the Weight of Water ſuſtained by it. Let H, h denote the Heights of the Column of Water ſuſtained between the two Glaſs Planes and of the Cylinder ſuſtained in a ſmall Glaſs Pipe; B, p the Breadth of the Column and Periphery of the Cylinder; and D, d the Thickneſs of the Column and Diameter of the Cylinder: And then the attractive Power which ſuſtains the Column will be as HBD, or as B, becauſe H is as $\frac{1}{D}$; and the attractive Power which ſuſtains the Cylinder will be as $\frac{hpd}{4}$, or as $\frac{p}{4}$, or as p, becauſe h is as $\frac{1}{d}$.

Hence

Hence it appears, that the attractive Power which ſuſtains the Water ariſes only from thoſe Parts of the Glaſs which are contiguous to the Surface of the elevated Water; or more truly, from the Parts of a narrow Surface of the Glaſs, whoſe Edge touches the lower Surface of the Water, and whoſe Height is the ſmall given Diſtance to which the attractive Power with which Glaſs attracts Water reaches; and therefore, the attractive Powers of the Glaſs Planes and ſmall Glaſs Pipe will be as 2B and p. Now the Powers are as the Weights ſuſtained by them, that is, $2B . p :: HBD . \frac{hpd}{4}$: Whence HD will be equal to $\frac{hd}{2}$; and when D is equal to $\frac{d}{2}$, H will be equal to h.

One

One and the fame fmall Glafs Pipe will fuftain different Weights of different Fluids, as appears from this Table:

Fluids.	Heights in Inches.	Denfi-ties.	Weights.
Oil of Vitriol	1. 1	17245	18969
Water p. 6. Sal Gem p. $\frac{3}{4}$	1. 73	10921	18893
Water p. 6. Sal Gem p. $\frac{1}{2}$	1. 72	10642	18304
Water p. 8. Common Salt p. $\frac{1}{2}$	1. 67	10447	17446
Water p. 6. Salt-petre p. $\frac{1}{2}$	1. 71	10447	17864
Spirit of Vitriol	1. 63	11860	19331
German Spa-Water	1. 75	10111	17694
Common Water cold	1. 75	10000	17500
Common Water boiling hot	1. 64	9781	15040
Good Blood	1. 64	10400	17056
Serum of good Blood	1. 65	10300	16995
Serum in a Dropfy	1. 65	10171	16782
Urine	1. 60	10270	16432
Saliva	1. 54	10100	15554
Milk of a Cow	1. 42	10279	14596
Gall of an Ox	1. 2	10335	12402
Small Beer	1. 44	10111	14559
Cyder	1. 3	10111	13144
Vinegar	1. 23	10279	12643
Common Ale	1. 2	10300	12360
Red Wine	1. 15	9930	11419
Punch	1. 12	10055	11261
Oil Olive	1. 14	9130	10408
Oil of Turpentine	0. 81	9244	7487
Sal Volatile Oleofum	0. 84	8774	7370
Brandy	0. 75	9320	6990
Spirit of Wine rectified	0. 73	8324	6076
Spirit of Harts-horn	1. 44	9802	14114

In

In the firſt Column are the Names of the Fluids, in the ſecond the Heights to which they roſe in one and the ſame Glaſs Pipe, in the third the Denſities of the Fluids, and in the fourth the Weights ſuſtained by the ſame Pipe. I obtained the Weights by multiplying the Heights into the Denſities. For the Weights of Cylinders are as their Magnitudes and Denſities taken together, or as their Heights and Denſities taken together if their Baſes be equal: But the Baſes of all the Cylinders of different Fluids ſuſtained by one and the ſame Pipe are equal: And therefore, the Weights of ſuch Cylinders are as their Heights and Denſities taken together.

Hence it appears, that one and the ſame Glaſs Pipe attracts different Fluids with different Degrees of Force. It attracts Spirit of Vitriol more ſtrongly than Oil of Vitriol, Oil of

Vitriol

Vitriol more ſtrongly than Water impregnated with Salt, Water impregnated with Sal Gem and Nitre more ſtrongly than common Water cold, common Water cold more ſtrongly than the Animal Fluids and common Water made boiling hot, the Animal Fluids more ſtrongly than fermented Liquors, fermented Liquors more ſtrongly than Oils, and Oils more ſtrongly than ardent Spirits.

Since the ſame Glaſs Pipe attracts different Fluids with different Degrees of Force; it is evident, that it attracts the Parts of ſome Fluids more ſtrongly than thoſe of others; and by Conſequence, if equal Quantities of all the Fluids of this Table were mixed together, it would ſuck in different Parts of this heterogeneous Fluid in different Proportions. It would ſuck in more Parts of Water impregnated with Salt than

than of Oil or ardent Spirits. The Parts leaſt attracted would be driven off, to make way for thoſe which are moſt attracted to enter into the Pipe; as in a Fluid where the Force of Gravity alone takes place the lighter Bodies are forced to aſcend, to make way for the Deſcent of Bodies which are heavier.

Sir *Iſaac Newton* has proved from Experiments, that the Particles of Light attract ardent Spirits and Oil more ſtrongly than Water: And by Conſequence, if we ſuppoſe a ſmall Pipe to be formed out of the Particles of Light, and one End of it to be dipped into a heterogeneous Fluid formed out of equal Quantities of all the Fluids of this Table intimately mixed together; this Pipe would attract the Parts of Oil and ardent Spirits more ſtrongly than thoſe of Water, and would ſuck in more Parts of the two former than of the latter. The Fluid therefore drawn out of the heterogeneous Fluid by this Pipe, would be different from the Fluid drawn out of it by a ſmall Glaſs Pipe; for two Fluids will be different, when they either conſiſt of different Parts, or of the ſame Parts mixed in different Proportions.

Now ſince Pipes of different Natures muſt draw off different Fluids from one and the ſame heterogeneous Fluid; it follows, that the ſecerning Pipes of the Glands, according to their different Natures and Diſpoſitions, ſuck in various Juices from the Blood, which is a heterogeneous Fluid conſiſting of a great Variety of Parts. And conſequently, the *Propoſition* is true.

Propo-

Propoſition XXXI.

IF Human Bodies have the ſame Number of correſponding Glands, if correſponding Glands have the ſame Number of correſponding ſecerning Pipes ariſing out of correſponding Blood-Veſſels, if the Lengths of correſponding Pipes be as the Lengths of the Bodies, if the Bodies be ſituated alike with reſpect to the Horizon, their Hearts be alike free from the Influences of diſturbing Cauſes, and their Blood be alike ſaturated with Parts fit for Secretion; the Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the ſeſquiplicate Ratios of the Diameters of correſponding Blood-Veſſels and of the ſubduplicate Ratios of the Forces *which move the ſecerned Humours through* *corresponding secerning Pipes, directly; and of the subduplicate Ratios of the Lengths of the Bodies, inversly. If* Z, z *denote the Quantities discharged by two corresponding Glands in a given Time;* F, f *the Forces which move the Humours through two corresponding secerning Pipes;* D, d *the Diameters of two corresponding Blood-Vessels; and* L, l *the Lengths of the Bodies; I say, that* $Z . z :: D\sqrt{\frac{DF}{L}} . d\sqrt{\frac{df}{l}}$.

For, allowing the Suppositions made in this *Proposition* to be true, it is evident, that the Quantities of Humour discharged by corresponding Glands in a given Time, will be as the Quantities discharged by any of their corresponding secerning Pipes in that Time: But the Quantities discharged by corresponding secerning Pipes in a given Time,

Time, will be as the Squares of their Diameters and the Velocities of the Humour flowing thro' them taken together; or as the Squares of the Diameters of the Blood-Veſſels out of which the Pipes ariſe and the Velocities of the Humour flowing through the Pipes taken together, becauſe the Diameters of the Pipes are as the Diameters of the Blood-Veſſels out of which they ariſe; and the Velocities of the Humour flowing thro' correſponding Pipes, will by *Prop.* 1. be in Ratios compounded of the direct ſubduplicate Ratios of the Forces which move the Humour thro' them; and the inverſe ſubduplicate Ratios of the Diameters and of the Lengths of the Pipes, or of the Diameters of correſponding Blood-Veſſels and of the Lengths of the Bodies: And therefore, allowing the Suppoſitions in this *Propoſition*, the Quantities

tities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of correſponding Blood-Veſſels and of the ſubduplicate Ratios of the Forces which move the Humour thro' correſponding ſecerning Pipes, directly; and of the ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels and of the Lengths of the Bodies, inverſly; that is, $Z . z :: D^2\sqrt{\frac{F}{DL}} . d^2\sqrt{\frac{f}{dl}}$. But $D^2\sqrt{\frac{F}{DL}} . d^2\sqrt{\frac{f}{dl}} :: D\sqrt{\frac{DF}{L}} . d\sqrt{\frac{df}{l}}$: And therefore, $Z . z :: D\sqrt{\frac{DF}{L}} . d\sqrt{\frac{df}{l}}$.

Cor. 1. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as their Diameters, or as the Diameters of correſponding Blood-Veſſels; the Quantities of Humour diſcharged by by correſponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of correſponding Blood-Veſſels directly, and of the ſubduplicate Ratios of the Lengths of the Bodies inverſly. And the mean Quantities of Humour diſcharged in a given Time, will be in ſubduplicate Ratios of the Lengths of the Bodies.

If F. f :: D. d; then will Z. z :: $\frac{D^2}{\sqrt{L}}$. $\frac{d^2}{\sqrt{l}}$. And ſince by *Cor.* 4. *Prop.* 12. the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, are in the ſubduplicate Ratios of the Lengths of the Bodies; if D, d denote the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and Z, z the mean Quantities of Humour diſcharged by correſponding Glands in a given Time; then Z. z :: $\sqrt{L}$. $\sqrt{l}$.

Cor.

Cor. 2. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the internal Surfaces of the Pipes, that is, as their Diameters and Lengths taken together, or as the Diameters of correſponding Blood-Veſſels and Lengths of the Bodies taken together; the Quantities diſcharged by correſponding Glands in a given Time, will be in the duplicate Ratios of the Diameters of correſponding Blood-Veſſels. And the mean Quantities diſcharged by correſponding Glands in a given Time will be as the Lengths of the Bodies. If F. f :: D L. dl; then will Z. z :: D^2. d^2. And, ſuppoſing D, d, Z, z to denote mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and mean Quantities of Humour diſcharged by correſponding Glands in a given Time; then Z. z :: L. l.

Cor. 3. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the Capacities of the Pipes, or as the Capacities of correſponding Blood-Veſſels; the Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels. And the mean Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies. If $F. f :: D^2L. d^2l$; then will $Z. z :: D^2\sqrt{D}. d^2\sqrt{d}$. And ſuppoſing D, d, Z, z to denote mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and mean Quantities of Humour diſcharged by correſponding Glands in a given

Time; then, ſince the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths are in the ſubduplicate Ratios of the Lengths of the Bodies, Z. z :: $L \times L^{\frac{1}{4}}$. $l \times l^{\frac{1}{4}}$.

Cor. 4. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the Capacities of the Pipes, or as the Capacities of correſponding Blood-Veſſels; the Sums of the Quantities diſcharged by all the correſponding Glands, or any given Number of them, in a given Time, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels: For, ſince the Diſcharges of any two correſponding Glands are in theſe Ratios; the Sum of the Diſcharges of all the Glands, or of any

any given Number of correſponding Glands, will be in the ſame Ratios. If S, s denote thoſe Sums, then S. s :: $D^2\sqrt{D}$. $d^2\sqrt{d}$. And if S, s, D, d denote the mean Sums of the Diſcharges in a given Time and mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, each Mean being taken from a conſiderable Number of Bodies of the ſame Length; then, ſince the mean Diameters of correſponding Blood-Veſſels are in the ſubduplicate Ratios of the Lengths of the Bodies, S. s :: $L\times L^{\frac{1}{4}}$. $l\times l^{\frac{1}{4}}$.

Of the Discharges of Human Bodies.

Proposition XXXII.

THE Mean Quantities of Food and Discharges in a natural Day, taken from all the Food and Discharges of a Month, are nearly equal in healthful Bodies.

For I have found by statical Experiments, that tho' the Food and Discharges of healthful Bodies be rarely equal in single Days; yet the mean Quantities in a natural Day, taken from all the Food and Discharges of a Month, are always nearly equal. And therefore, the *Proposition* is true.

Here it may be proper to take notice of three Things, which by

Some

Some may be thought Objections against this *Propoſition.*

The *firſt* is the Difference which has been found in the Weight of a grown healthful Body at different Seaſons of the Year. *Sanctorius* ſays, that temperate Bodies are three Pounds heavier in Winter than they are in Summer, and that the Augmentation and Diminution of Weight are made in Autumn and the Beginning of Summer. And in this Climate I have found, that healthful Bodies are heavier in Winter than in Summer, and that they grow heavier in Autumn, and lighter again in the Spring; but for want of a ſufficient Number of Experiments, I have not been able to determine, how much grown healthful Bodies taken one with another are heavier in Winter than they are in Summer. They cannot be much heavier; for I have obſerved, and the ſame obtains

tains in *Italy*, that any conſiderable Increaſe of Weight made in a ſmall Compaſs of Time, is very apt to cauſe Diſeaſes. If we ſuppoſe Bodies to be four *Averdupois* Pounds heavier, and that they gain this Weight in Autumn and loſe it in the Spring, in the Space of two Months; then the Food will exceed the Diſcharges in Autumn and fall ſhort of them in the Spring, by an Ounce in a Day taking one Day with another: But an Ounce is ſo ſmall a Difference between the Food and Diſcharges in a natural Day, that they may be truly ſaid to be nearly equal in a grown healthful Body at all Seaſons of the Year.

The *ſecond* is the Change which is continually made in the Weight of a growing Body; but if we conſider the Quantity and Time of its Growth, we ſhall find its Food and Diſcharges in a natural Day to be very

very nearly equal. For if a Child when it is born weigh 12 Pounds, and in twenty Years (which I ſhall ſuppoſe to be the Time of growing) come to weigh 168 Pounds; the Food will exceed the Diſcharges in a natural Day, taking one Day of the whole Time of its Growth with another, by ſomething more than the third part of an Ounce. 'Tis true a healthful Child from its feeding plentifully, ſleeping much, and wanting Exerciſe, grows much more the firſt half Year than it does afterwards in the ſame Compaſs of Time; and yet even then there is but little Difference between the Food and Diſcharges in a natural Day, taking one Day with another. For if its Weight when it is born be doubled in the firſt half Year, the Food will exceed the Diſcharges by little more than an Ounce in a Day, taking one Day with another. Therefore the

Food

Food and Difcharges in a natural Day may be truly faid to be nearly equal in a healthful Body.

The *third* is the great Change which we frequently fee made in the Weights of grown Bodies in the Compafs of a few Years; and yet if we confider the Quantity of the Change, and the Time in which it is made; we fhall find little Difference between the Food and Difcharges in a natural Day, taking one Day of that Time with another. For if a grown Body gain in Weight 50 Pounds in five Years Time, the Food will not exceed the Difcharges by half an Ounce in a natural Day, taking one Day of that whole Time with another.

Cor. 1. If N, n denote the mean Quantities of Food in a natural Day of two healthful Bodies, taken from their whole Quantities of Food in a Month;

Month; and P, U, S, p, u, s the mean Quantities of their Perſpiration, Urine, and Stool, taken from the whole Quantities of thoſe Diſcharges in a Month; then by this *Propoſition*, N=P+U+S, and n=p+u+s.

Cor. 2. If a healthful Body at all Seaſons of the Year take daily the ſame Quantity of Food in every Month, taking one Day of the Month with another; the daily Sum of the Diſcharges in every Month, taking one Day of the Month with another, will be likewiſe nearly the ſame at all Seaſons of the Year. And therefore, if either Perſpiration, Urine, or Stool be greater in ſome Months of the Year than in others; the Sum of the other two will be as much leſs: Otherwiſe the Sum of the three could not be given.

The Truth of theſe two *Corollaries* will appear from the following Table.

Months.	Breakfast.	Dinner.	Supper.	Morning. Urine.	Morning. Perspiration	Afternoon. Urine.	Afternoon. Perspiration	Night. Urine.	Night. Perspiration	Stool.	Total Urine.	Total Perspiration.	Total Discharges.	Total Food.
April.	23$\frac{11}{30}$	43$\frac{29}{30}$	16$\frac{13}{60}$	8$\frac{23}{60}$	11	17$\frac{77}{180}$	11$\frac{17}{60}$	16$\frac{11}{12}$	15$\frac{97}{180}$	5$\frac{16}{60}$	41$\frac{8}{9}$	37$\frac{5}{6}$	84$\frac{12}{60}$	83$\frac{33}{60}$
May.	23$\frac{9}{10}$	41$\frac{21}{60}$	28$\frac{19}{30}$	7$\frac{11}{60}$	13$\frac{7}{60}$	17$\frac{22}{60}$	11$\frac{37}{60}$	16$\frac{5}{12}$	19$\frac{11}{60}$	7$\frac{5}{12}$	40$\frac{29}{30}$	44$\frac{73}{120}$	93$\frac{1}{3}$	92$\frac{16}{60}$
June.	27$\frac{1}{5}$	48$\frac{2}{15}$	15$\frac{1}{10}$	7$\frac{2}{15}$	15$\frac{41}{60}$	12$\frac{1}{10}$	12$\frac{21}{30}$	13$\frac{26}{30}$	22$\frac{23}{30}$	5$\frac{21}{60}$	33$\frac{23}{30}$	51$\frac{3}{20}$	90$\frac{7}{30}$	90$\frac{13}{30}$
July.	25$\frac{59}{60}$	41$\frac{7}{60}$	15$\frac{32}{60}$	7$\frac{47}{60}$	14$\frac{5}{6}$	10$\frac{3}{10}$	12$\frac{17}{60}$	12$\frac{3}{10}$	19$\frac{19}{60}$	5$\frac{51}{60}$	30$\frac{23}{60}$	46$\frac{26}{60}$	82$\frac{2}{3}$	82$\frac{38}{60}$
August.	22$\frac{1}{6}$	42$\frac{7}{20}$	21$\frac{1}{12}$	7$\frac{9}{26}$	17$\frac{5}{13}$	10	13$\frac{2}{13}$	12$\frac{9}{26}$	20$\frac{9}{13}$	4$\frac{21}{72}$	29$\frac{3}{4}$	52	86	85$\frac{86}{96}$
Septem^r^.	18$\frac{43}{60}$	48	19$\frac{3}{4}$	7$\frac{1}{2}$	13$\frac{29}{60}$	13$\frac{7}{60}$	11$\frac{1}{60}$	15$\frac{1}{2}$	19$\frac{14}{15}$	5$\frac{9}{60}$	36$\frac{7}{60}$	44$\frac{1}{2}$	85$\frac{23}{30}$	85$\frac{4}{5}$
October.	18$\frac{51}{60}$	45$\frac{53}{60}$	15$\frac{21}{60}$	7$\frac{1}{5}$	9$\frac{39}{60}$	13$\frac{41}{63}$	10$\frac{1}{10}$	16$\frac{39}{60}$	17$\frac{31}{60}$	4$\frac{23}{60}$	37$\frac{7}{12}$	37$\frac{7}{12}$	79$\frac{9}{12}$	80$\frac{5}{12}$
Novem^r^.	21$\frac{8}{13}$	40$\frac{12}{13}$	15$\frac{3}{52}$	7$\frac{17}{26}$	8$\frac{49}{52}$	12$\frac{39}{52}$	8$\frac{9}{13}$	16$\frac{9}{13}$	18$\frac{1}{52}$	4$\frac{37}{52}$	37$\frac{5}{52}$	35$\frac{17}{26}$	77$\frac{6}{13}$	77$\frac{31}{52}$

This

This Table was made from a Courſe of Statical Experiments. The natural Day is divided into three Parts, Morning, Afternoon, and Night; the Morning contains ſix Hours from eight to two, the Afternoon ſix Hours from two to eight, and the Night the remaining twelve Hours. I obſerved the Food and the Diſcharges in theſe three Parts of the Day, every Day for eight Months together; and with the Means taken from all the Food and all the Diſcharges in the ſeveral Months, I compoſed the Table: From which it appears,

Firſt, That Perſpiration and Urine vary in their Quantities at different Seaſons of the Year, and that as one encreaſes the other leſſens. In *April* and *May* they were nearly equal, only Urine exceeded Perſpiration a little in *April*, and was exceeded by it a little in *May*. In the three Summer Months, *June*, *July*, and *Auguſt*, taken one with another, Perſpiration exceeded Urine in the Proportion of about 5 to 3. In *October* and *November* they were nearly equal again, only Urine exceeded Perſpiration a little in *November*. At the End of this Month I was interrupted, and hindered from carrying on the Experiments throughout the whole Year, as I at firſt intended; but I repeated them for about ten Days in cold froſty Weather, and found that Urine then exceeded Perſpiration as much as Perſpiration exceeded Urine in Summer.

Secondly, That Stool is but a ſmall Diſcharge when compared with Perſpiration and Urine, and is but little influenced by the Seaſons of the Year in healthful Bodies. It was a little larger in *May* than in the other Months, from a gentle *Diarrhæa*,

rhæa, for about twenty Days in that Month. And it was a little leſs in *October* and *November*, from the Quantity of Food being leſs in thoſe Months than in the others.

Thirdly, That the daily Food and daily Diſcharges taken from all the Food and all the Diſcharges of a Month, are nearly equal at all Seaſons of the Year in healthful Bodies, only the Diſcharges fall a little ſhort of the Food in Autumn, and exceed it a little in the Spring. The Difference between the Food and Diſcharges at theſe Seaſons ariſes, from Perſpiration being more diminiſhed in Autumn by the Cold of the external Air, than Urine is increaſed; and more increaſed in the Spring by the Warmth of the Air, than Urine is diminiſhed. Urine takes up ſome Time at theſe Seaſons to have its Increaſe and Diminution made equal to the Diminution and Increaſe of Perſpi-

Perſpiration. And hence it is that Bodies grow heavier in Autumn and lighter in the Spring; and by Conſequence, that they are a little heavier in Winter than they are in Summer. The Change of Weight in Spring and Autumn is not great in healthful Bodies, and probably does not exceed above three or four Pounds; for I have known an Increaſe of five or ſix Pounds to have cauſed a Diſeaſe in the latter End of Autumn: But an Increaſe of four Pounds in two Months is at the Rate only of about an Ounce in a Day: And the ſame Increaſe in three Months is at the Rate only of about two third Parts of an Ounce in a Day, taking one Day with another.

Pro-

Propoſition XXXIII.

SUppoſing the ſame Things as are ſuppoſed in the 31ſt Propoſition *and its* 3d Corollary; *and that the Quantities diſcharged by Stool in a natural Day, taken from the whole Quantities of that Diſcharge in a Month, are in the ſame Proportion as the daily Diſcharges of other correſponding Glands taken from their whole Diſcharges in a Month; the Sum of the Diſcharges by Perſpiration, Urine, and Stool in a natural Day, taken from their whole Quantities in a Month, will in healthful Bodies of different Lengths be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels, that is,* $P+U+S. \; p+u+s :: D^2\sqrt{D}. \; d^2\sqrt{d}$.

For

For the Sums of Perſpiration and Urine in a natural Day, taken from their whole Quantities diſcharged in a Month, are in that Proportion by the *4th Corollary* of the 31*ſt Propoſition:* And the Quantities diſcharged by Stool in a natural Day, taken from the whole Quantities of that Diſcharge in a Month, are by Suppoſition as the daily Diſcharges of other correſponding Glands taken from their whole Diſcharges in a Month: And therefore, the Sums of the three Diſcharges in a natural Day, taken from the wholes of their reſpective Quantities in a Month, will be in the ſame Proportion, that is, $P+U+S. p+u+s :: D^2\sqrt{D}. d^2\sqrt{d}$.

Cor. 1. If the Diameters of correſponding Blood-Veſſels be in the ſubduplicate Ratios of the Lengths of the Bodies; the Sums of the Quantities of Perſpiration, Urine, and Stool

Stool discharged daily by healthful Bodies of different Lengths, when each Quantity is taken from the whole of that Discharge for a Month, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies. If D. d:: $\surd$L. $\surd$l, then will P+U+S. p+u+s:: $L \times L^{\frac{1}{4}}$. $l \times l^{\frac{1}{4}}$.

If this *Proposition* obtain in healthful Bodies; then will this *Corollary* obtain, when the Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies. They are in this Proportion in perfectly regular and well-proportioned Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; and the mean Diameters of corresponding Blood-Vessels of all healthful Bodies of different Lengths, when each Mean is taken from the Diameters of thoſe Veſſels in a conſiderable Number of Bodies of each Length, are likewiſe in the ſame Proportion: And therefore, if this *Propoſition* be true, the mean Sums of the Quantities of the Diſcharges in a natural Day of healthful Bodies of different Lengths, when the Quantity of each Diſcharge is taken from its whole Quantity in a Month, will be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies: But thoſe Sums of the Diſcharges are equal to the mean Quantities of Food in a natural Day, taken from the whole Quantities of Food in a Month, by *Cor.* 1. *Prop.* 32: And by Conſequence, the mean Quantities of Food in a natural Day of healthful Bodies of two different Lengths, will be in Ratios compounded of the ſimple

ple and ſubquadruplicate Ratios of theſe Lengths. This Proportion obtains nearly in the *Royal* and *Blew-Boys Hoſpital.* For upon inquiring into their Food I found, that taking one Day of the Week, and conſequently one Day of the Month, with another, the Quantities of Food taken daily by Bodies whoſe Lengths are 69 and 54 Inches, are 109 and $85\frac{1}{2}$ *Averdupois* Ounces: But theſe Quantities of Food are nearly in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies; only the Food of the Boys compared with that of the Men, is greater than in this Proportion by about $5\frac{1}{2}$ Ounces in a Day; which may be owing to the Food of the Boys being ſomething more liquid than the Food of the Men, and to their uſing more Exerciſe. In the Food of the Boys, the liquid part is to the ſolid part a little more than 3 to 1; and in that of the Men, a little more than 2½ to 1.

Lengths of the Bodies in Inches.	The Lengths into the biquadrate Roots of the Lengths.	Whole Quantities of Food or Discharges in a natural Day in *Averdup.* Ounces.
72	2097	116
69	1988	109
66	1881	103
60	1670	91½
54	1463	80
48	1263	69
42	1069	58½
36	882	48
30	702	38
24	531	29
18	371	20

This Table in its third Column contains the mean Quantities of Food, or mean Quantities of the Discharges, Difcharges, in a natural Day, of healthful Bodies of the Lengths fet down in the firft Column. I computed it by the fecond Column, which contains the Products of the Lengths and biquadrate Roots of the Lengths of the Bodies, taking 109 *Averdupois* Ounces as a proper Quantity of Food for well-proportioned Bodies 69 Inches in Height, on Suppofition that the liquid part of the Food to the folid is in the Proportion above-mentioned. The Food of very young Children, as being wholly liquid, fhould be more than is affigned them by this Table; but what the exact Quantity is I know not for want of Experiments.

Cor. 2. If this *Propofition* be true, as it appears to be by the laft *Corollary*; the Sums of the Difcharges by Perfpiration, Urine, and Stool, in in a natural Day, taken from their whole Quantities in a Month, will in Bodies of equal Lengths be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of their Quantities of Blood. For the Squares of the Diameters of correſponding Blood-Veſſels are as the Quantities of Blood in Bodies of equal Lengths, that is, $D^2 . d^2 :: Q . q$; and the Square-Roots of the ſame Diameters, are as the biquadrate Roots of the Quantities, that is, $\sqrt{D} . \sqrt{d} :: Q^{\frac{1}{4}} . q^{\frac{1}{4}}$: And therefore, $P + U + S . p + u + s :: Q \times Q^{\frac{1}{4}} . q \times q^{\frac{1}{4}}$.

For Inſtance, if the Quantities of Blood in two healthful Bodies of the ſame Length be as 3 to 2, then $P + U + S . p + u + s :: 39480 . 23784$. If the Length of the Bodies be ſix Feet, and the Quantity of Food in a Day of that Body which has the greater

greater Quantity of Blood be 116 Ounces; the Quantity of Food in a Day of the other Body will be about 70 Ounces.

Propoſition XXXIV. Problem V.

TO determine the Proportion which Perſpiration bears to Urine at different Seaſons of the Year, at different Times of the natural Day, under different Kinds and Degrees of Exerciſe, in Bodies of different Ages, and Bodies which are nouriſhed by different Kinds of Food.

I. Perſpiration with reſpect to Urine is greater in Summer than in Winter. It was near three times as great in the Body from which the Table in *p.* 258 was made, and it is generally greater, tho' not in the

the ſame Proportion, in healthful Bodies. A warm Air warms the Skin and increaſes Perſpiration, and a cold Air cools the Skin and leſſens Perſpiration; but as Perſpiration increaſes or leſſens, Urine on the contrary leſſens or increaſes by that Table. The Proportion of Perſpiration to Urine is regulated by the Heat of the Skin; and as far as the Heat of the Skin is increaſed or leſſened by the Heat or Cold of the external Air, the Proportion of Perſpiration to Urine will be increaſed or leſſened by the Heat or Cold of the external Air. Accordingly, I have obſerv'd Perſpiration to have been only equal to, nay ſometimes to have fallen ſhort of, Urine in the Summer-Time, in Bodies which have been little expoſed to the Heat and Cold of the external Air. And as far as I can judge from the Obſervations I have made,

this

this chiefly happens in Bodies whoſe Skins are naturally cool by a ſpare Diet, or a languid Motion of the Blood, or both.

II. From the Table *p.* 258 it appears, that both Perſpiration and Urine are greater in the Afternoon than in the Morning, in the Day than in the Night. But as the Man from whom that Table was made, walked ſome Hours every Day, and generally more in the Morning than in the Afternoon; we cannot from that Table determine theſe Diſcharges, and conſequently their Proportions to one another at different Times of the Day in Bodies which are at Reſt. That I might be ſatisfied of this, I took the Quantities of Perſpiration and Urine diſcharged by two healthful Men B and D, in the ſeveral Hours of the Day for four Days together in very hot

Weather, and with the mean Quantities of the Diſcharges in thoſe Hours, compoſed the following Table.

Hours.	B Perſpiration.	B Urine.	D Perſpiration.	D Urine.
6	$1\frac{7}{8}$	$0\frac{15}{16}$	2	1
7	$1\frac{5}{6}$	1	$1\frac{2}{5}$	1
8	2	1	$1\frac{1}{2}$	$1\frac{1}{5}$
9	2	$1\frac{1}{6}$	$1\frac{4}{5}$	$1\frac{3}{10}$
10	2	$1\frac{1}{2}$	$1\frac{9}{10}$	1
11	$1\frac{3}{4}$	1	$1\frac{2}{5}$	1
12	$2\frac{1}{3}$	1	$1\frac{4}{5}$	1
1	$2\frac{1}{3}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1
2	2	1	$1\frac{1}{2}$	1
3	$3\frac{1}{2}$	$1\frac{1}{2}$	2	1
4	$2\frac{1}{3}$	2	$1\frac{1}{2}$	$1\frac{1}{7}$
5	$2\frac{1}{3}$	2	$1\frac{4}{5}$	1
6	$2\frac{2}{3}$	2	2	1
7	2	2	2	1
8	$2\frac{1}{3}$	$2\frac{1}{3}$	2	1
9	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$
10	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$

B took 86 Ounces of Food in a Day, and D only 63: They both eat their Breakfaſt

Breakfaſt at eight a Clock in the Morning, dined at two, and ſupped at eight at Night. It is to be obſerved, that the Numbers correſponding to the Hour 6 in the Morning, are the mean Quantities of Perſpiration and Urine which were drawn off from the Blood in every Hour of the Night, taking one Hour with another.

Setting aſide Exerciſe, and ſuppoſing the natural Day to be divided into three equal Parts, Morning, Afternoon, and Night, and the Morning to begin at ſix a Clock; the Quantities perſpired by B and D in the Morning, Afternoon, and Night, were nearly by this Table, 16, 20, 15, and 13, 14, 16; and the Quantities of Urine made by theſe Bodies in the ſame Times, were nearly 9, 15, 7½, and 8, 8½, 9. The Proportions of Perſpiration to Urine in theſe Times, were 177, 133, 200, in B;

 and

and 162, 164, 177, in D. Hence we learn, that the Proportion of Perſpiration to Urine is greater in the Night when Bodies are at Reſt, than it is in the Day-time; that there is no great Difference in this Proportion in theſe Times, in Bodies which eat ſparingly and drink but little Wine, which was the Caſe of D; and that in Bodies which eat plentifully and drink Wine, this Proportion is often leſs in the Afternoon than it is in the Morning, which was the Caſe of B. Wine in moſt Bodies increaſes the Diſcharge by Urine; and as that Diſcharge increaſes, the Proportion of Perſpiration to it will neceſſarily leſſen; unleſs Perſpiration be increaſed in the ſame Proportion as Urine is increaſed, which I believe very ſeldom, if ever, happens. Hence we may judge of the Proportion of Perſpiration to Urine at different Times

of

of the natural Day, in Bodies which are at Reſt; and at the ſame time ſee, that notwithſtanding the Inequalities of this Proportion in different Parts of the natural Day, the Proportion of Perſpiration to Urine in the whole natural Day, is nearly the ſame at the ſame Seaſon of the Year in healthful Bodies; it was nearly 162 in B, and 168 in D.

III. The Proportion of Perſpiration to Urine, is increaſed by all thoſe Exerciſes which increaſe the Motion of the Blood and warm the Skin. Two Men of nearly the ſame Height and Weight walked a Mile in half an Hour, and in that Time each perſpired about $3\frac{1}{2}$ Ounces, which is about three times as much as they ordinarily perſpire in the ſame Time in the Heat of Summer without Exerciſe. This Degree of Exerciſe gave a glowing Warmth

to

to the Skin, but did not make them ſweat, but would have cauſed a gentle breathing Sweat, had it been continued much longer. The ſame Men walked above two Miles in half an Hour, and in that Time one perſpired nine Ounces, and the other eight, which was about eight times as much as they ordinarily perſpire in the ſame Time in the Heat of Summer without Exerciſe. This Degree of Exerciſe made them ſweat profuſely. A third Man, who was fat and much taller than either of the others, walked two Miles in half an Hour, and in that Time perſpired thirteen Ounces and a half, which was about nine times as much as his Summer's Perſpiration in the ſame Time without Exerciſe. And a Boy ſeven Years old, who without Exerciſe perſpired half an Ounce in half an Hour in the Heat of Summer, by walking at

ſuch

ſuch a Rate as gave a gentle Warmth to his Skin, but did not make him ſweat, perſpired about three times as much in the ſame Time. At the Beginning of the Exerciſe of Walking I have obſerved, that Urine has been increaſed as well as Perſpiration; but on continuing the Exerciſe, Urine in a very little Time has decreaſed again, and grown leſs than it was before the Exerciſe, by the large Diſcharge which was made by the Skin. If we ſuppoſe the Quantity of Urine not to be leſſened by Exerciſe, as it may not in Perſons who by Drink ſupply the Loſs which is made by Perſpiration, then will the Proportion of Perſpiration to Urine be 6 to 1, in Perſons who walk at ſuch a Rate as to give a glowing Warmth to their Skins, but not to cauſe Sweat, and 16 to 1 in Perſons who walk at ſuch a Rate as to ſweat profuſely, on

Sup-

Suppoſition that the Proportion of Perſpiration to Urine is 2 to 1 in the Heat of Summer. The Exerciſe of Riding increaſes Perſpiration, but neither ſo ſuddenly, nor in ſo great a Degree, as the Exerciſe of Walking, as appears from the following Inſtance. A healthful Man upwards of ninety Years of Age, who commonly without Exerciſe diſcharged four or five times as much by Urine as he did by Perſpiration, obſerved that in the Night, after riding ſeveral Hours the Day before, he always perſpired as much as he diſcharged by Urine. In this Caſe therefore, Perſpiration to Urine was increaſed by Riding in the Proportion of 4 or 5 to 1.

IV. The Proportion of Perſpiration to Urine in Bodies of different Ages will be greater or leſs, as the external Heat of the Body is greater

greater or leſs: But the external Heat of the Body is leſs in old Bodies than it is in others: And therefore, the Proportion of Perſpiration to Urine will be leſs in old Bodies than it is in others. In the old Man above-mentioned, this Proportion was leſs than in Bodies in the Vigour of their Age in the Heat of Summer, in the Proportion of 1 to 8 or 10.

V. The Proportion of Perſpiration to Urine in Bodies nouriſhed by different Kinds of Meats and Drinks will be greater or leſs, as thoſe Meats and Drinks are fitted to warm or cool the Skin by warming or cooling the Blood, and increaſing or leſſening its Motion. As to Drinks, Water and watry Liquors drunk hot warm the Skin and increaſe Perſpiration; and drunk cold they cool the Skin, and increaſe Urine. Three or four Quarts of Chalybeate Waters will paſs off by Urine in many Bodies in leſs than three Hours Time. Wine and other fermented Liquors drunk cold and in large Quantities frequently paſs off very quick by Urine, but not altogether ſo quick as cold Water; and drunk hot they increaſe Perſpiration. Water impregnated with Nitre is colder and more diuretick than plain Water. As to Meats, thoſe which are dry and warming increaſe Perſpiration; and thoſe which are moiſt and cooling increaſe Urine. Ripe Apples increaſe Perſpiration, as appears from the following Inſtance. The old Man above-mentioned, whoſe Perſpiration in the eighty-ſixth Year of his Age, was not above ¼th part of his Urine, by eating three Quarters of a Pound of mellow Apples at Night with Bread, brought his Perſpirati-

on

on to be nearly equal to his Urine, leſs only in the Proportion of 13 to 16. That this Change in Perſpiration was owing to the Apples, appeared from hence, that on his leaving them off, his Perſpiration grew leſs, and returned to what it was before he began to eat them.

From theſe Inſtances it appears, that the Proportion of Perſpiration to Urine is increaſed or leſſened by Meats and Drinks, as they increaſe or leſſen the Heat and Motion of the Blood.

FINIS.

ERRATA.

Page 4. *Line* 2, 3. *for*, as often as there are phyſical Points, *read*, for every phyſical Point. *p.* 8. *l.* 6. *f.* if, *r.* and. *p.* 10. *l.* 20. *f.* the Place, *r.* the Hole or Place. *p.* 14. *l.* 8. *f.* By, *r.* From. *p.* 17. *l.* 18. *f.* 12 to 17, *r.* 17 to 12. *p.* 35. *l.* 16. *f.* H+S. *r.* $\frac{H+S}{L}$. *p.* 38. *l.* 4, 5, 6. *dele* and the Capacities of the two Pipes are as the Capacities of the two Syſtems. *p.* 46. *l.* 12. *f.* the ſubduplicate, *r.* the inverſe ſubduplicate. *p.* 48. *l.* 12. *f.* $17\frac{1}{2}$, *r.* $17\frac{1}{8}$. *l.* 19. *f.* $206\frac{5}{8}$, *r.* $106\frac{5}{8}$. *p.* 51. *l.* 13, 14, 15. *dele* and the Capacities of two correſponding Pipes, as the whole Capacities of the two Syſtems. *p.* 79. *f.* $3\frac{1}{2}$, *r.* $3\frac{1}{3}$. *p.* 93. *l.* 5, 6. *f.* Tremor, *r.* Tremors. *p.* 145. *l.* 7. *f.* Heart, *r.* Hearts. *p.* 183. *l.* 12. *after* Wind, *add*, A the Degree of Heat in the Wind. *p.* 184. *l.* 23. *f.* be different, *r.* be given. *p.* 227. *l.* 13. *f.* Mo-on, *r.* Motion. *p.* 119. *f.* Cor. 4. *r.* Cor. 3. *p.* 132. *l. ult. f.* Prop. 12. *r.* Prop. 13.